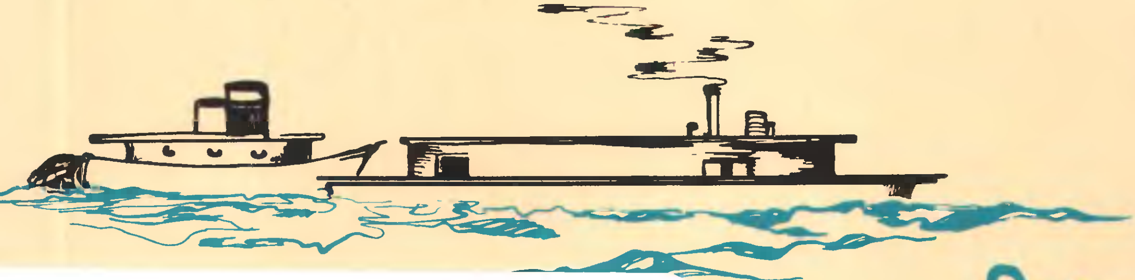
OSWEGO RIVER BASIN PLANNING REPORT

eastern oswego ground water



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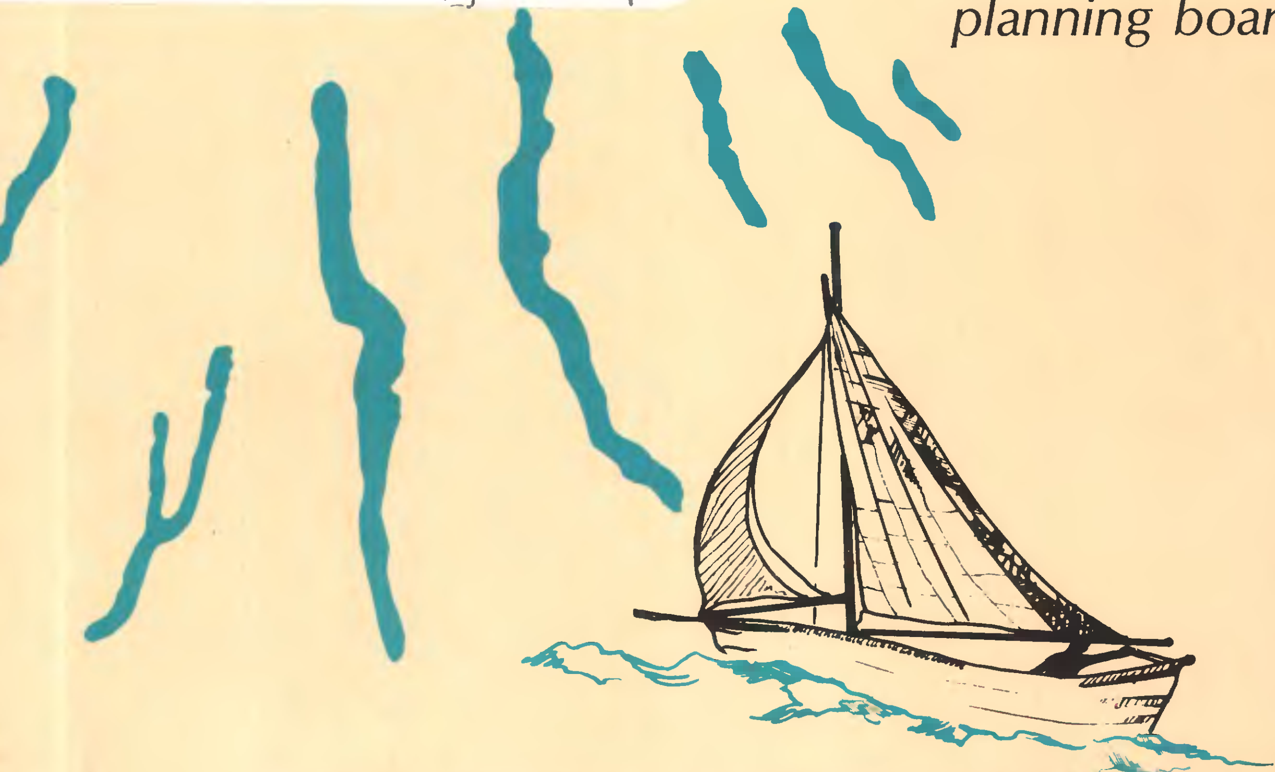

THE NEW YORK STATE WATER RESOURCES COMMISSION
CONSERVATION DEPARTMENT • DIVISION OF WATER RESOURCES

GROUND-WATER RESOURCES IN THE EASTERN OSWEGO RIVER BASIN, NEW YORK

Prepared for the
Eastern Oswego Regional Water Resources
Planning Board

by

I. H. Kantrowitz

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

in cooperation with

THE NEW YORK STATE CONSERVATION DEPARTMENT
DIVISION OF WATER RESOURCES

STATE OF NEW YORK
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Basin Planning Report ORB-2
1970

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by
I.H. Kantrowitz

ABSTRACT

The Eastern Oswego River basin comprises approximately 2,500 square miles in central New York. About 35 percent of the 600,000 people living in the basin rely on ground water to meet their water needs. Ground water sufficient for domestic supplies can generally be obtained. Sources of large supplies, such as for industries or municipalities, are present although not widespread.

The principal aquifers in the basin are unconsolidated deposits of sorted and stratified sand and gravel. The most prolific sand and gravel aquifers are those that are hydraulically connected to streams or rivers and, when pumped, can be recharged by surface water. Sixteen such aquifers have been tentatively identified; the potential yield of individual aquifers ranges from 1 mgd (million gallons per day) to 60 mgd, the total yield being about 280 mgd. Currently, less than 5 mgd is being withdrawn from these aquifers. Those surficial sand and gravel aquifers not connected to streams are recharged only by infiltrating precipitation and runoff from adjacent areas. The yields of such aquifers range from less than 0.4 to as much as 20 mgd, depending largely on the surface area of the particular aquifer and on climatic and topographic variations. Still other sand and gravel aquifers are buried beneath relatively impermeable materials and receive recharge only by the slow movement of ground water from adjacent deposits. The yields of these buried aquifers generally range from 1 to 4 mgd.

Two bedrock units, the limestone and middle shale units, crop out in a broad belt across the central part of the basin and are capable of yielding large quantities of water, particularly wherever the units are crossed by streams. Unlike wells in sand and gravel aquifers, the yield of any one well in bedrock cannot be predicted with any degree of accuracy.

Ground water in much of the Eastern Oswego River basin is of poor quality. Wells tapping either the limestone and middle shale units or the unconsolidated deposits overlying these units are likely to yield very hard water. Water from the middle shale unit may be so hard as to make treatment uneconomical. Large parts of the basin are underlain by

relatively shallow salty ground water. The salt water is derived in part from layers of rock salt within the middle shale unit and in part from upward movement of salt water from deeper parts of the bedrock. In general, some fresh water occurs above the salt water -- generally in the unconsolidated deposits and in the upper 20 feet of the bedrock.

A total of about 21 mgd is withdrawn from the ground-water reservoir from public, domestic, industrial, and commercial supplies. This is only 2 percent of the estimated natural ground-water recharge of 1,000 mgd. Almost all the domestic pumpage and part of the public, industrial, and commercial pumpage is returned to the ground by septic tanks or other waste-disposal methods. The remainder, the net withdrawal, is probably less than 10 mgd, or less than 1 percent of the available supply.

WHY AND HOW THIS STUDY WAS MADE

Water has frequently been called the lifeblood of the earth. Its importance to man, and, in fact, to all forms of life, cannot be overemphasized. The growth of our cities and industries, the expansion of our suburban areas, and the increased productivity of our farms all depend on adequate water supplies. In particular, ground water is of vital importance to farmers and to rural and suburban homeowners; ground water is almost always the only readily available source for their water supply. Ground water is also important to the people responsible for public and industrial water supplies because it may often be the most economical, if not the only source of supply. It is for these people, the farmers, homeowners, water managers, and the engineers, geologists, and well drillers who may be called upon to help them, that this report has been written.

The U.S. Geological Survey has among its several responsibilities the measurement, description, and appraisal of the Nation's water resources. The Survey, in cooperation with the New York State Water Resources Commission, is studying the water resources of selected areas in New York State. The reports resulting from these studies are published by the Water Resources Commission.

The location of the Eastern Oswego River basin is shown in figure 1. The principal aim of this report is to describe how much and what kind of ground water is available at any particular site within the basin. A secondary aim is to help make possible the sound development, management, and conservation of ground water by describing what it is, where and how it occurs, and how it can best be withdrawn for man's use.

Ground water is a commodity that in its natural underground habitat can neither be seen nor directly measured. Fragments of information are gathered from many sources and are pieced together to form a picture of ground-water conditions. Among the people who generously supplied this information are well owners and well drillers, and various personnel of the New York State Departments of Transportation, and Health, and the Cayuga and Tompkins County Health Departments. Most of the well records used in this report were collected by J. A. Tannenbaum. The investigation was supervised by R. C. Heath, former District Chief of the Albany office of the Geological Survey.

The water resources of parts of the Eastern Oswego River basin have been studied previously. Reports on the ground-water resources of Wayne County (Griswold, 1951) and Seneca County (Mozola, 1951) have been published by the New York Water Power and Control Commission. A report on the water resources of the Utica-Rome area was published by the U.S. Geological Survey (Halberg, Hunt, and Pauszek, 1962). At the present time (1970) the Survey, under the direction of Robert J. Dingman, District Chief, is studying the quality and quantity of surface water in the Eastern Oswego River basin. The surface-water study together with this ground-water report will constitute an appraisal of the water resources of the basin.

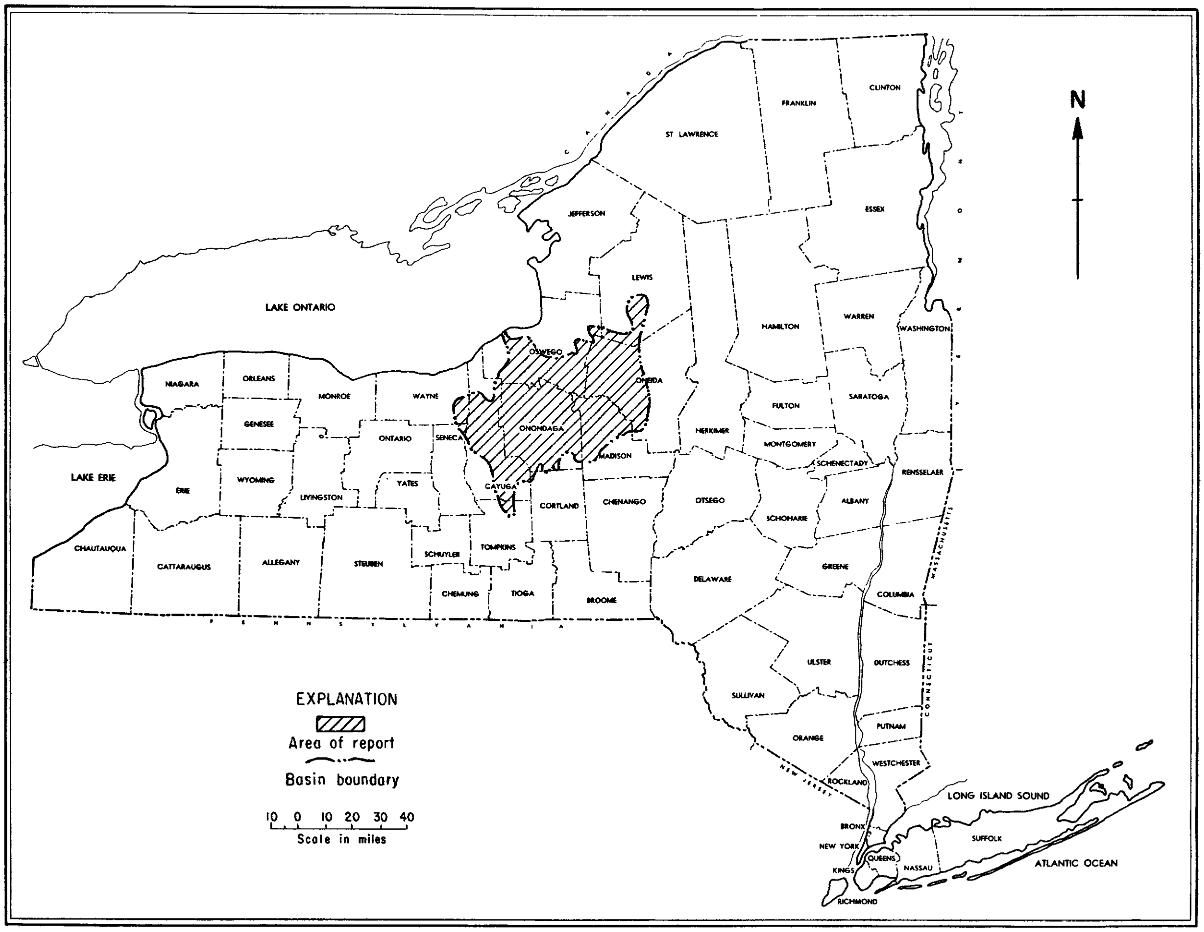


Figure 1.--Map of New York State showing the location of the Eastern Oswego River basin.

THE EASTERN OSWEGO RIVER BASIN

The combined drainage basins of the Oneida and Oswego Rivers and the eastern half of the Seneca River form the Eastern Oswego River basin. Included in the approximately 2,500 square mile basin in central New York are almost all of Onondaga County, large parts of Cayuga, Madison, Oneida, and Oswego Counties, and small parts of Cortland, Lewis, Seneca, Tompkins, and Wayne Counties. As of 1964 about 600,000 people lived in the area, more than 70 percent of them in cities, villages, or suburbs. The city of Syracuse is the population, transportation, and commercial center of the basin although the cities of Auburn, Fulton, Oneida, Oswego, and Rome and several of the larger villages are also sites of considerable industrial activity.

The basin is one of great physical diversity and, on the basis of landforms, can be divided into the three regions shown in figure 2. The southern part of the basin, a series of valleys and hills that trend north-south, is the Appalachian Upland, a region of similar geological and physical features that extends southward as far as Alabama. Another region of hills and valleys, the Tug Hill Upland, occupies the northeastern part of the basin. It is similar in form to the Appalachian Upland except that the hills are broader and flatter. The Ontario-Mohawk Lowland, part of a lowland extending from Buffalo to Albany, occupies the central and north-western part of the study basin. The Lowland is generally flat without any dominant trend to the land forms.

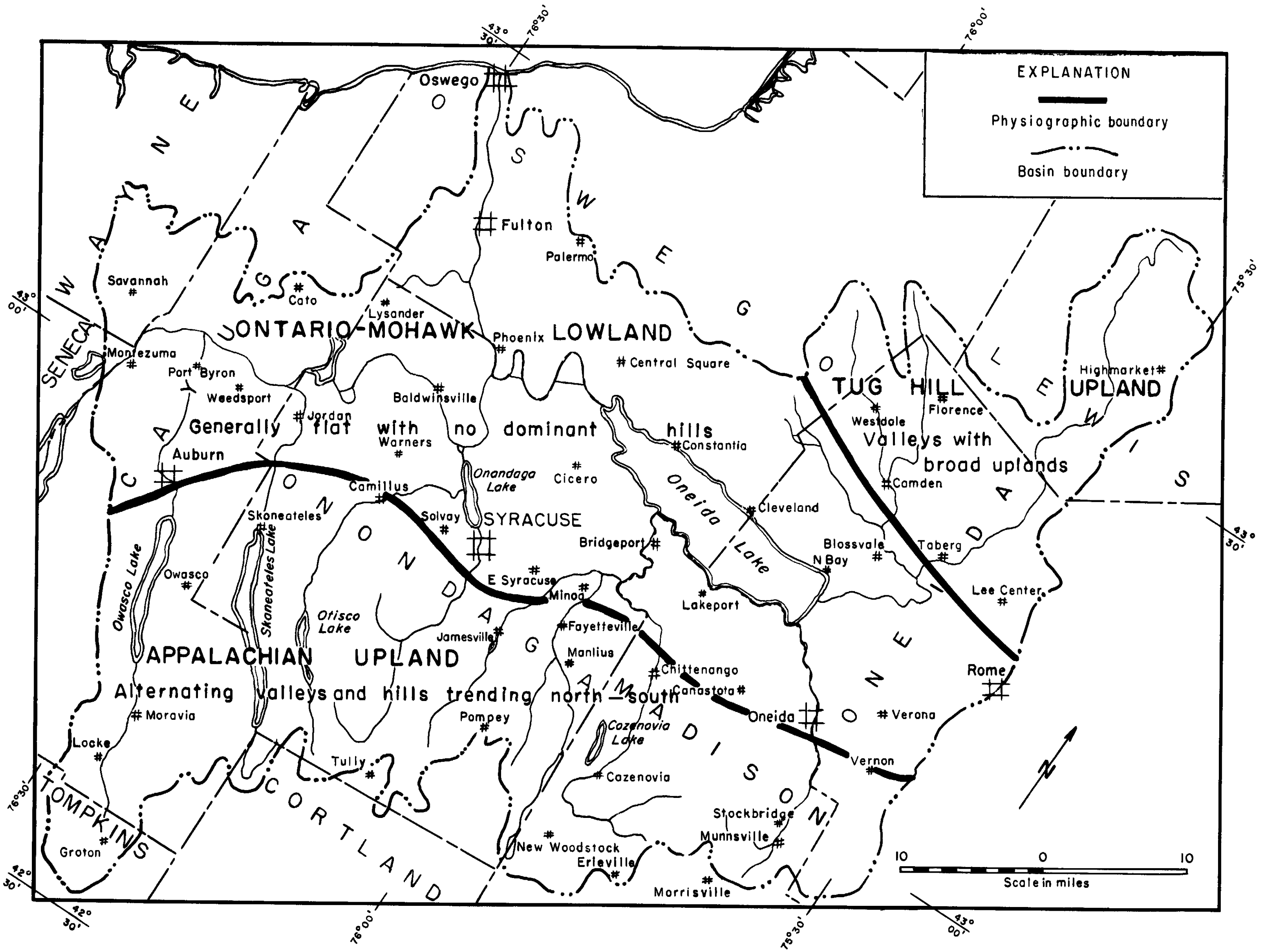


Figure 2.--The Eastern Oswego River basin is made up of three distinct physiographic regions.

THE GENERAL WATER SITUATION

Water supplies can be obtained in all parts of the Eastern Oswego River basin. The quantity and quality of the water, however, range from an almost unlimited supply of excellent quality water available to most city dwellers to a minimum supply of largely unpotable water available to some rural householders. We can get some idea of this range by looking at the present use of water in the basin, the source of this water, the major water problems, and the potential sources of the water that will be needed in the future.

PRESENT DEVELOPMENT OF WATER RESOURCES

One-billion gallons of water will cover more than 3,000 acres of land to a depth of 1 foot, cover a square mile to a depth of almost 5 feet, or fill to capacity a 3-mile high water tower 100 feet in diameter. Anyway you look at it, one billion gallons is a lot of water. Yet considerably more than one billion gallons of water are used in the Eastern Oswego River basin each day! By far the greatest part of this water is used to generate electricity and is returned to its source undiminished in quantity and unchanged in chemical quality. The remainder of the water, more than 300 mgd, is used for various purposes in homes, factories, commercial establishments, and public buildings throughout the basin. Probably more than 95 percent of this water is available for reuse; that is, less than 15 mgd is actually consumed during use.

Broadly speaking, water supplies come from two sources: surface water (streams, lakes, and reservoirs) and ground water (wells and springs). Of the total water used in the basin (not counting that used for power generation), 93 percent comes from surface-water sources and only 7 percent from wells and springs. Water supplies may also be separated into:

1. Public supplies--water supplied to home, industrial, and commercial users by municipally or privately owned systems;

2. domestic supplies--water supplied to private homes by individually owned systems; and

3. industrial and commercial--water supplied to a factory or commercial establishment by a company-owned system.

The estimated annual withdrawals of water in the basin by source and type of supply is shown in table 1.

Although the total withdrawal of ground water is small compared to that of surface water, the figures in table 1 are somewhat misleading. Only about one-third of the surface water withdrawn by the major public supplies is used in households; the remainder is used in factories, stores, offices, for fire-fighting and other public requirements, or is lost through leakage from water mains. Actually, about 35 out of every 100 people living

Table 1.--Estimated withdrawals of ground water and surface water, exclusive of power generation, in the Eastern Oswego River basin during 1964

Source of water	Estimated average annual withdrawals (million gallons per day)			
	Public supplies	Domestic supplies	Industrial and commercial supplies	Total
Surface water	95	0	200	295
Ground water	8	7	6	21
All	103	7	206	316

in the basin use ground water to meet their basic water needs. Figure 3 shows the areas served by public supplies; elsewhere ground water from individually owned wells and springs is the principal supply for farmers and homeowners, and is an important supply for industries, particularly in areas distant from surface-water sources. Also, as can be seen in figure 3, ground water is the source of almost all but the largest of the public-supply systems.

WATER PROBLEMS

Large amounts of water are withdrawn every day from rivers and lakes in the Eastern Oswego River basin and smaller, although significant, amounts of water are withdrawn from wells and springs. So far the water-supply situation looks pretty good. But what happens to the millions of gallons of water used daily? Is the water changed? Where does it go after it is used? What about the reliability of supply where cities and villages draw water from lakes or reservoirs that get dangerously low each summer? And what might be done where wells don't supply enough water or supply water with unpleasant tastes or chemical properties? These, then, are the water problems in the basin: pollution, inadequate public supplies, low-yielding wells, and poor water quality. Most of these problems will be discussed in greater detail in subsequent sections of this report. For now let's briefly summarize the problems and look at the affected areas.

Figure 4 is a map of the basin showing:

1. The areas where well yields are likely to be low;

2. the areas where the chemical quality of ground water, and at times surface water, may be poor; and

3. the extent of stream pollution.

Inadequate public supplies are not shown in figure 4; in each instance where public supplies are inadequate, additional water is available either through increased development of present sources or through development of

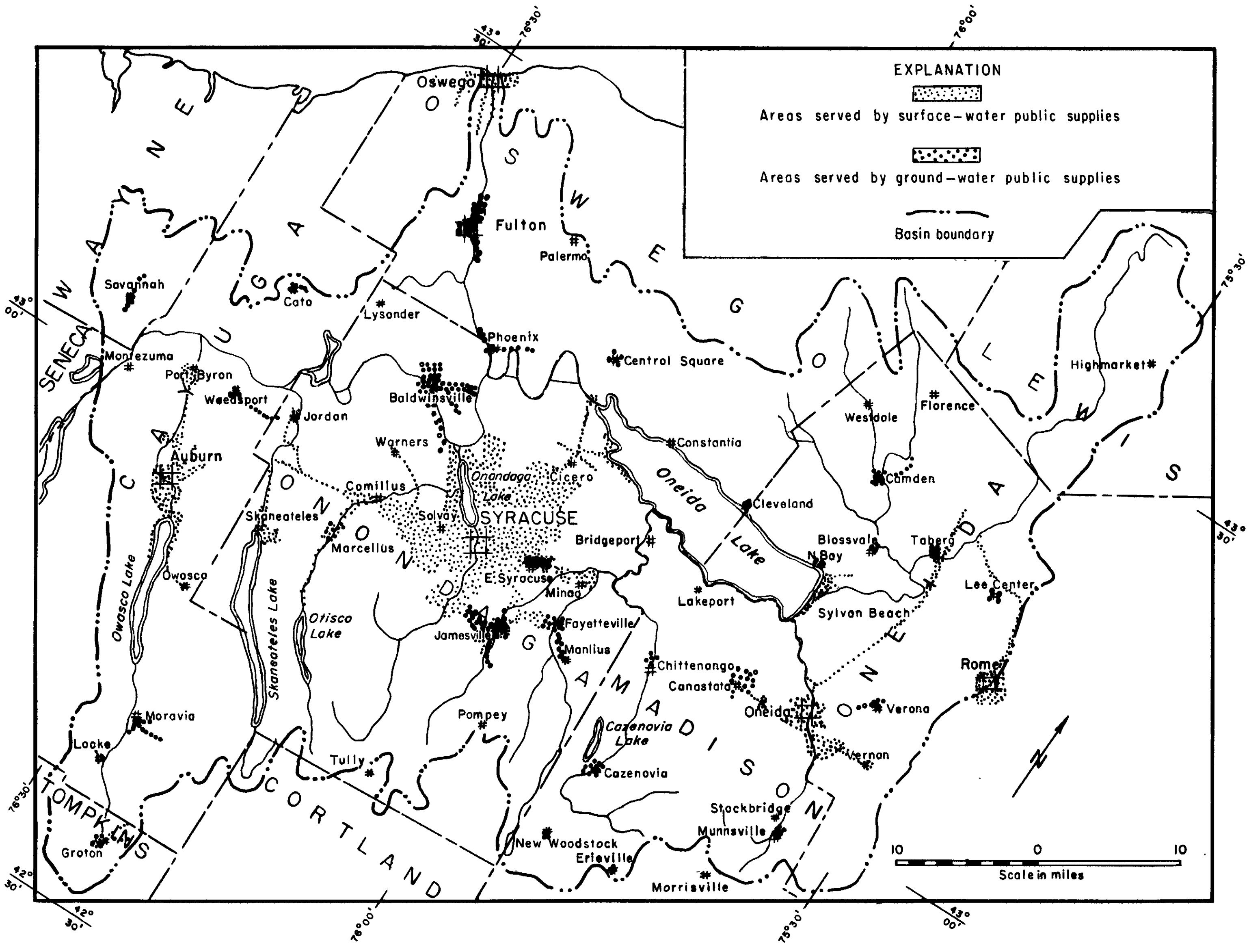


Figure 3.--Many of the people in the Eastern Oswego River basin are served by public-water supplies.

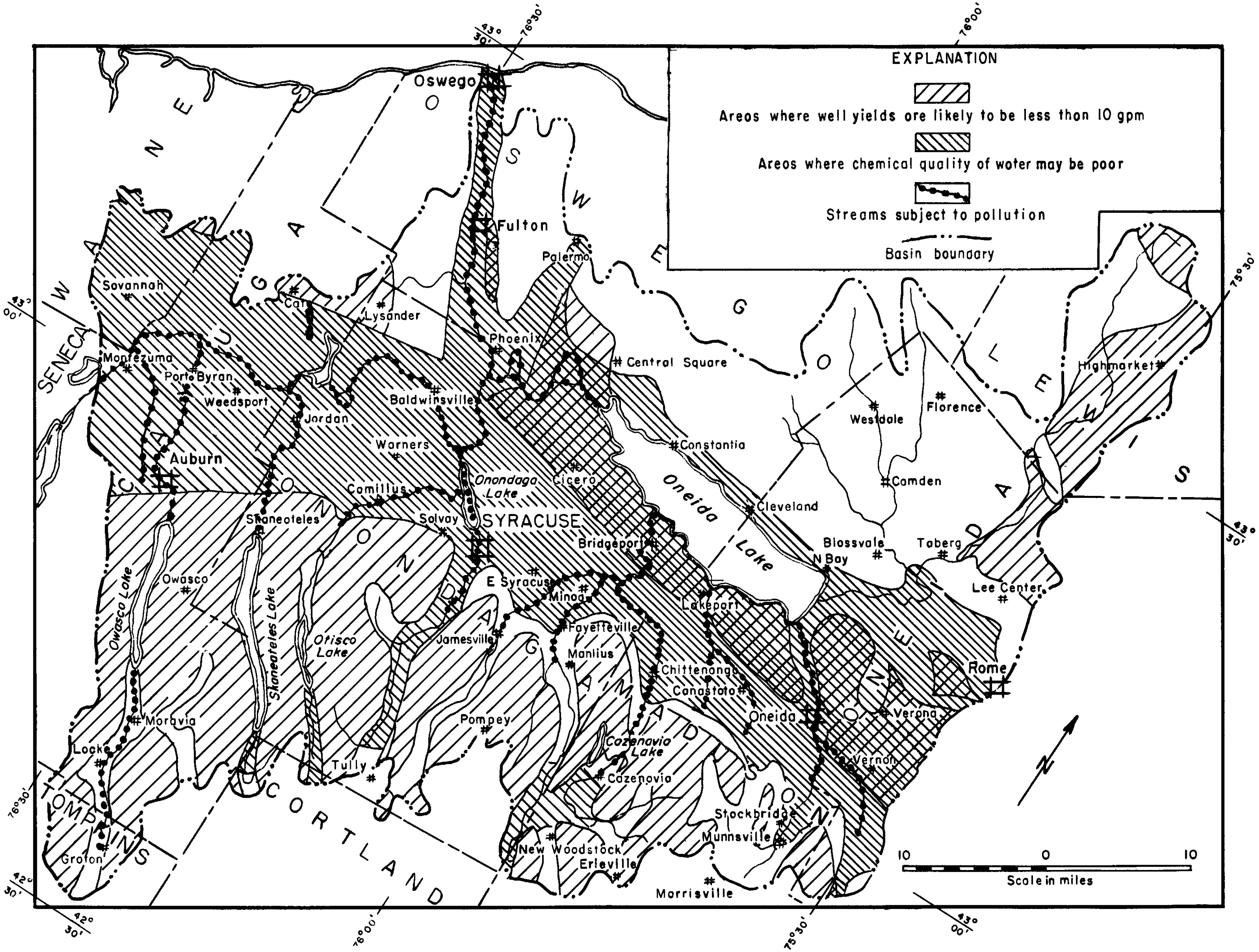


Figure 4.--Water problems in the Eastern Oswego River basin.

new sources. The major problem here is one of economic or legal restrictions, not a deficiency of water. With the completion of the pipeline from Lake Ontario to metropolitan Syracuse, water will be available, if needed, to supplement the supply of more than 60 percent of the people living within the basin.

About half the basin is underlain by rocks that generally yield less than 10 gpm (gallons per minute) to individual wells, as can be seen in figure 4. Well yields in this area generally range from about 3 to 6 gpm and are adequate for most domestic and farm needs; they are not adequate for most industrial and many commercial needs. The problem of well yields will be discussed in much more detail in the section on the availability of ground water.

Water problems may exist even where adequate quantities of water can be developed. All naturally occurring water contains some dissolved minerals, and ground water usually contains more of these minerals than surface water. This is what gives ground water its "flavor" and is why many people prefer well or spring water to the flatter-tasting water that comes from many surface reservoirs. In some cases, however, ground water may be so highly mineralized that it has an unpleasant taste, odor, color or undesirable chemical property. The parts of the basin where the quality of ground water is likely to be poor are shown in figure 4. In these areas ground water may be salty because of relatively large amounts of dissolved sodium chloride (common table salt), or it may be extremely hard and have an unpleasant mineralized taste because of large amounts of dissolved calcium sulfate (gypsum). The water in small streams draining these areas is also likely to be of poor quality especially during dry periods when most of their flow is ground-water seepage.

Much of the ground water and surface water south of the major band of poor quality water shown in figure 4 is also hard, but the concentrations of dissolved minerals in the water are not nearly as great. Rusty water (from dissolved iron or manganese) or water with an odor like that of rotten eggs (from dissolved hydrogen sulfide gas) occurs to some extent throughout the basin. The occurrence of poor quality water and methods of avoiding or treating it will be discussed in the section on the quality of the ground water.

Pollution is a direct result of the methods of waste-water disposal used in the area. Most industries and municipal sewage systems discharge used water into the nearest body of surface water, often with little or no treatment. Stream pollution shown in figure 4 is caused by the discharge of wastes containing such contaminants as chlorides, nitrates, bacteria, viruses, synthetic detergents, and various industrial chemicals. Wastes from unsewered villages and from rural dwellings are usually discharged into the ground by means of septic tanks. Such discharge may locally pollute the ground water and may be a hazard to improperly located or constructed water wells.

FUTURE DEVELOPMENT OF WATER RESOURCES

Like death and taxes, increased water use is one of the certainties we must learn to live with. Per capita consumption of water, that is, the total amount of water used for domestic, public, commercial, and industrial purposes divided by the total population, has been steadily rising in the past and will almost certainly continue to rise in the future. We see this increased water use in our own homes in the form of dishwashers, garbage-disposal units, and larger washing machines. Also, the rapid growth of suburban areas has caused an equally rapid growth of lawn sprinkling and other outdoor uses of water. Not so apparent, but even more significant, is the increased use of water by industries. Technological advances and increased productivity may often cause a parallel increase in water use. Therefore, even if the population of the basin remained constant in the future, total water use probably would increase. But the population is not expected to remain constant; according to the 1960 census, the Eastern Oswego River basin is the most rapidly growing area in the State. It is not unrealistic to assume that total water use by the year 2000 may be almost twice as much as it was in 1964 (table 1). Probably about 95 percent of all the water used, however, would be available for reuse.

Where will all this water come from? To answer this question, let's look at the three major types of water supplies: public, domestic, and industrial and commercial. Let's see what their future water needs are likely to be and how these needs can be met.

About 75 percent of the population of the basin is served by public-water supplies. In the future, this percentage will tend to increase as more of the rapidly growing suburban areas are incorporated into public-supply systems. At present the bulk of the water used for public supplies comes from surface-water sources. Because of the presence of the Finger Lakes, Lake Ontario, and numerous developed and undeveloped reservoir sites, surface water will likely be the principal source for the expanded public-supply systems. Despite this, ground water will continue to be the source of supply for a number of the smaller systems, many of which may experience sharp increases in water demand. Additional ground water is likely to be found in the areas shown in figure 5.

Before we become overly optimistic, however, let's glance back at figure 4. Many of the areas of possible large ground-water supplies shown in figure 5 coincide with the areas of poor water quality shown in figure 4. Future ground-water sources must be developed with a thought given to both the quantity and the quality of the supply. Many of the smaller public-supply systems are, nevertheless, favorably situated with regard to adequate sources of ground water. Many of them are also located close to the larger public-supply systems (fig. 3). In the future the managers of the smaller systems may want to purchase supplemental water rather than develop additional supplies of their own.

About 25 percent of the people in the basin obtain water from their own wells or springs. As the area becomes more highly urbanized, this percentage will decrease. Because of the increase in total population, however, the number of self-supplied rural and suburban households

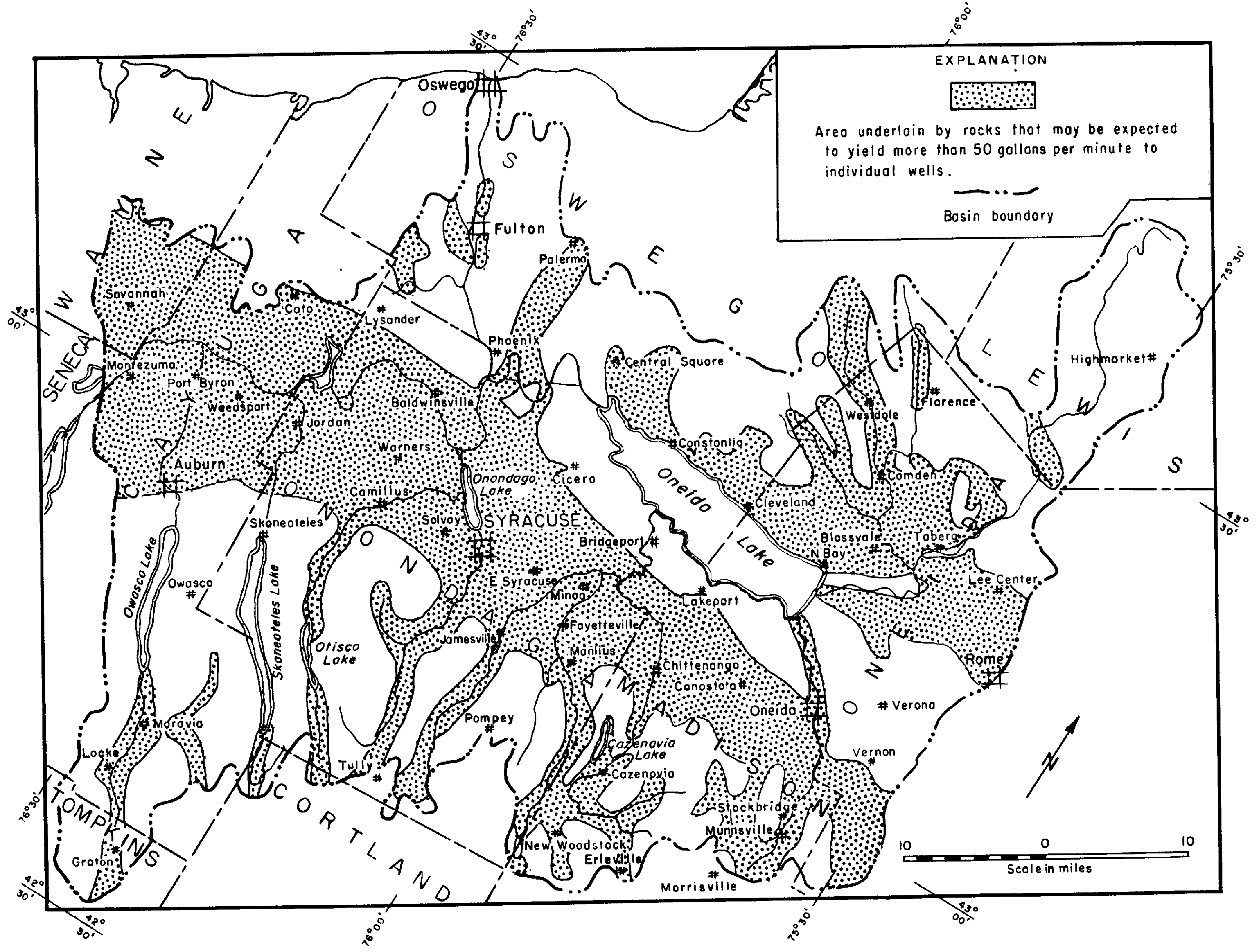


Figure 5.--Large supplies of ground water are available throughout much of the Eastern Oswego River basin.

is likely to increase. If the present trend continues, each of these households will use more water. The use of water on farms will also increase as modern farming and dairying practices become more widespread. Present withdrawals of ground water for domestic and farm supplies are but a fraction of the water available. Well yields of at least 1 gpm are available throughout the basin and even such low yields can be adequate for most domestic needs if sufficient water storage is provided. The quality of the water again must be considered. Water of a somewhat poorer quality than that of a public supply will generally be acceptable in a domestic supply. Also, small supplies of better water can often be obtained in areas where poor quality water is known to be present. Thus, ground water should prove adequate to meet the needs of the future rural and semirural population of the basin.

Industrial and commercial supplies account for more than 65 percent of the water used in the basin. Ever increasing amounts of water for cooling and processing will be needed to keep pace with the anticipated industrial expansion. Surface water will furnish the bulk of this water, just as it has in the past. However, factors such as a need to locate near raw materials or transportation facilities may focus industrial attention on areas distant from surface-water bodies. Industrial expansion into such areas may depend on the availability of adequate ground-water supplies. Figure 5 shows that quantities of water adequate for many industries can be obtained from ground water throughout much of the basin. For processing water, quality standards may be quite stringent and may eliminate many of the areas of potentially large supplies. On the other hand, quality is not as important when considering water to be used for cooling; in fact, because of its cooler summer temperature, ground water is generally preferred for cooling. The presence of large quantities of water suitable for many industrial purposes may prove an important factor in the continued economic growth of the basin.

WELL-NUMBERING SYSTEM

Each of the wells or springs for which information was collected during this investigation was given a number based upon its latitude and longitude. To do this, the basin was divided into rectangles, or grids, of one minute of latitude and one minute of longitude. Because all the basin lies within latitude 42° and 44° and longitude 75° and 77°, the first digits of the grid numbers ("4" and "7") can be omitted; they are the same for all locations. Only the second digit of the degree and the two digits of minutes are required to identify any one of the latitude or longitude grid lines, for example, 302 instead of 4302. Each rectangle in the grid system is numbered according to the latitude of its southern side and the longitude of its eastern side. This is illustrated in figure 6 where rectangle 302-602 is named for the lines of latitude and longitude intersecting at its lower right-hand corner. Wells or springs within each rectangle are numbered consecutively in the order they were inventoried; 302-602-1 was the first well or spring inventoried and 302-602-2Sp was the second. Springs are differentiated from wells by the addition of a suffix "Sp" after the number. On the well- and spring-location maps (pls. 3 and 4) the three-digit grid numbers are shown around the margin of the basin and only the sequential number of each well or spring is shown within the rectangles.

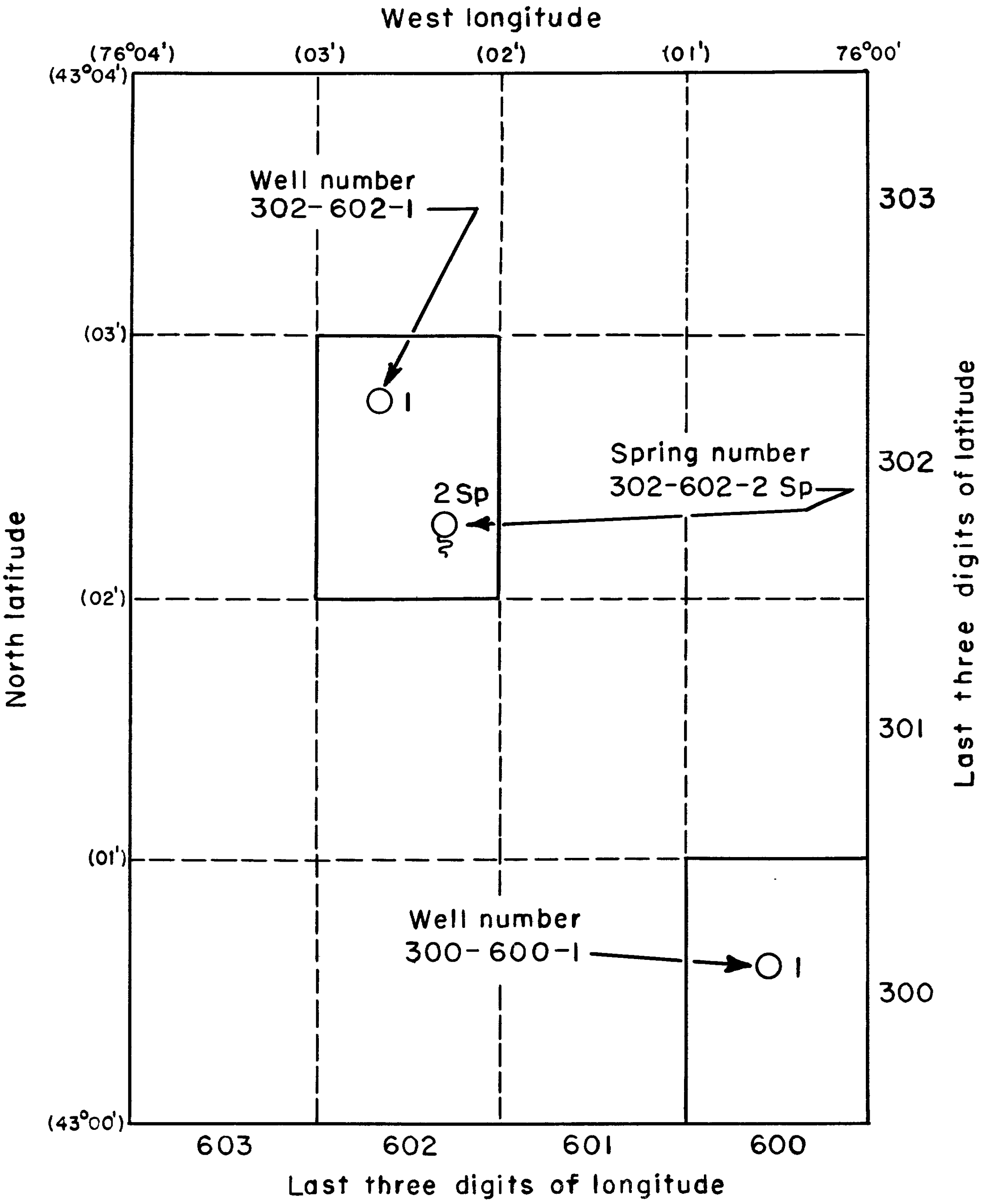


Figure 6.--Wells and springs are numbered according to their latitude and longitude.

AVAILABILITY OF GROUND WATER

The dictionary defines a reservoir as "a place where water is collected and kept for use when wanted." We all know of the spectacular dams built across river canyons in the western part of the country to create vast man-made lakes, or reservoirs. In the Eastern Oswego River basin dams built across streams have created Jamesville and DeRuyter Reservoirs, which were formerly used in the operation of the Erie Canal. Other artificial reservoirs have been created to store water for the cities of Oneida and Rome. Natural lakes may also be considered reservoirs because they store water. The Finger Lakes are both natural and artificial reservoirs; they are natural lakes whose water levels are now controlled by dams at their outlets.

All these reservoirs are easy to visualize; we can see the water, we can estimate how much of it there is, and we know how to make use of it. Not as easily visualized, however, is the vast quantity of water stored in the rocks beneath our feet. These rocks make up an underground reservoir holding more water than all the surface reservoirs within the basin combined. This underground reservoir fits our definition as well as do the surface reservoirs because it collects and keeps water for use when wanted.

To understand how much water is stored in the ground, and how it best can be removed, we will have to look at the rocks that comprise the underground or ground-water reservoir. We are really not so much interested in the rocks themselves as in the openings found within the rocks. Though we think of the earth as being a solid mass, most rocks in the upper 200 or 300 feet of the earth's crust contain a surprising volume of "empty" spaces. These spaces are generally filled with water -- the ground water that is the subject matter of this report.

In addition to acting as reservoirs, rocks also serve as pipelines because water moves through them in response to gravity. Ground-water movement is controlled by the size and smoothness of the rock openings and by the way they are interconnected. Engineers know that water can move most easily through large-diameter, straight, unrestricted pipes. Similarly, the larger, straighter, and smoother the connections between the openings in a rock mass, the more water the rock can transmit. The capacity of a rock to allow water to move through it is called permeability. Permeable rocks are called aquifers, that is, they are capable of yielding significant amounts of water.

To facilitate their description, the rocks in the basin may be divided into two major classes: (1) unconsolidated deposits, such as sand or clay; and (2) bedrock, such as limestone, sandstone or shale. These rock classes have different types of openings and behave differently as reservoirs and pipelines. It is important to keep in mind that both classes of rocks are almost always present beneath any site; the unconsolidated deposits occur as a mantle, completely covering the bedrock except for small areas where bedrock occurs at the surface.

At any site in the basin either the unconsolidated deposits, the bedrock, or both may be adequate sources of water supply. To find the best source of water at any particular site the following steps are suggested:

> Find out whether or not favorable sands or gravels are present from plates 1 or 2. If they are not present, a "rock well" may be indicated at the site in question. The distribution of bedrock is shown in plates 3 and 4. The relative advantages or disadvantages of the various sources of water are discussed in the text under "Water in the unconsolidated deposits" and "Water in the bedrock." Locations of wells and springs throughout the area are shown in plates 3 or 4. Those near the proposed site will give an indication of results that may be expected. Data pertaining to those wells and springs are shown in tables 10 and 11. Geologic sections in plate 6 illustrate a number of typical areas and may be helpful in deciding what the geologic conditions are at the site in question. The section on "Quality of ground water" points out the kind of water available from the different formations. Analyses of well and spring water are given in table 6.

The sections "Yield of unconsolidated aquifers" and "Yield of bedrock aquifers" will be helpful if additional technical data or if larger than average supplies of water (for factories, municipalities, etc.) are required.

The final decision on a source of water will depend on: (1) the amount of water needed and the amount available from the possible sources; (2) the quality of the available water; and (3) cost factors such as the type and depth of well required to tap each of the possible sources, necessary treatment of the water, and cost of pumping.

Before discussing how much water is available, it would be well to briefly consider how much water is actually needed. Some useful data on average water requirements for homes and farms are shown in table 2. Most water needs in the basin range from about 100 gpd (gallons per day) for small households to more than 4,000 gpd for some larger farms. Because there are 1,440 minutes in a day, a well that yields only 1 gpm will be adequate for most household needs and a well that yields 2 to 3 gpm will be adequate for most farm needs. When low yielding wells prove inadequate for peak demands, such as running a garden hose for long periods, adequate water-storage facilities should be provided. Such facilities can be as simple as a larger pressure tank or as involved as the two-pump system with a storage tank or reservoir shown in figure 7.

WATER IN THE UNCONSOLIDATED DEPOSITS

The term "unconsolidated deposits" refers to all the earth material found above the bedrock. In the Eastern Oswego River basin, most of this material was formed from and deposited on the bedrock by massive continental

Table 2.--Approximate water-supply requirements for homes and farms 1/

User	Water use (gpd)
Member of household (total use)........	50
Horse, dry cow, or beef animal.........	12
Milking cow............................	35
Hog....................................	4
Sheep..................................	2
One-hundred chickens...................	4
Type of use	**Water use (gallons)**
Tub bath...............................	35
Shower.................................	20 to 60
Flushing toilet........................	6
Dishwasher (per load)..................	3
Washing machine (per load).............	50
Backwashing domestic water softener....	100
Garden hose (per minute)...............	3 to 5

1/ Modified from "Water Well Handbook" (Anderson, 1963, p. 183)

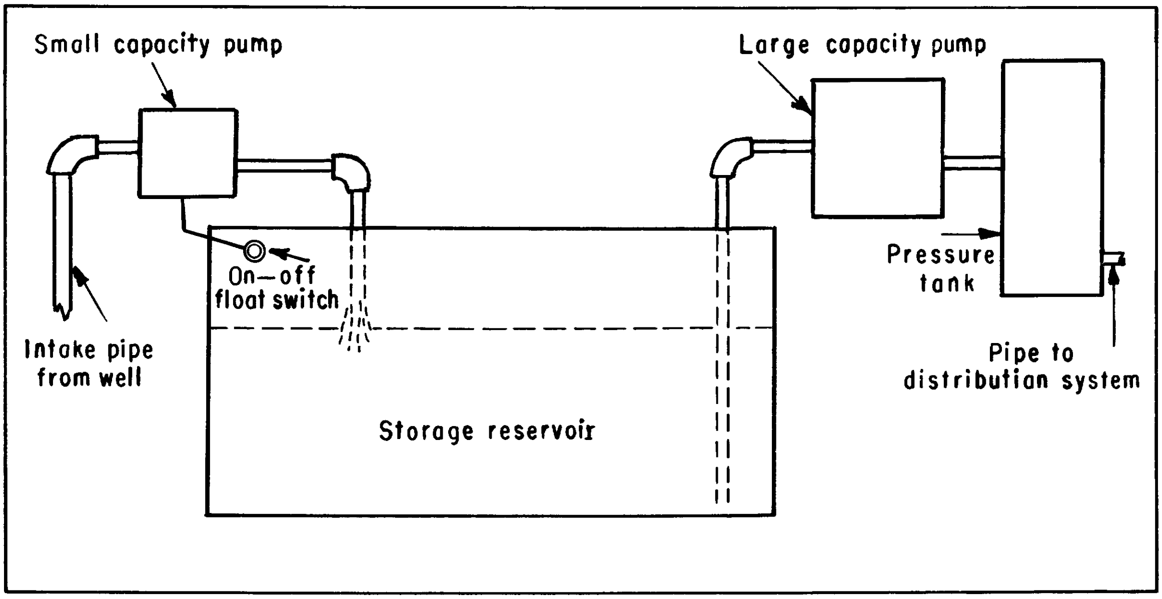


Figure 7.--A two-pump system with a storage reservoir is one way to obtain "additional" water from a low yield well.

ice-sheets, or glaciers. These glaciers covered northern North America during much of the past million years and completely melted from the basin only about 10,000 years ago. Geologically speaking, the unconsolidated deposits are quite young and have been little modified by erosion or weathering.

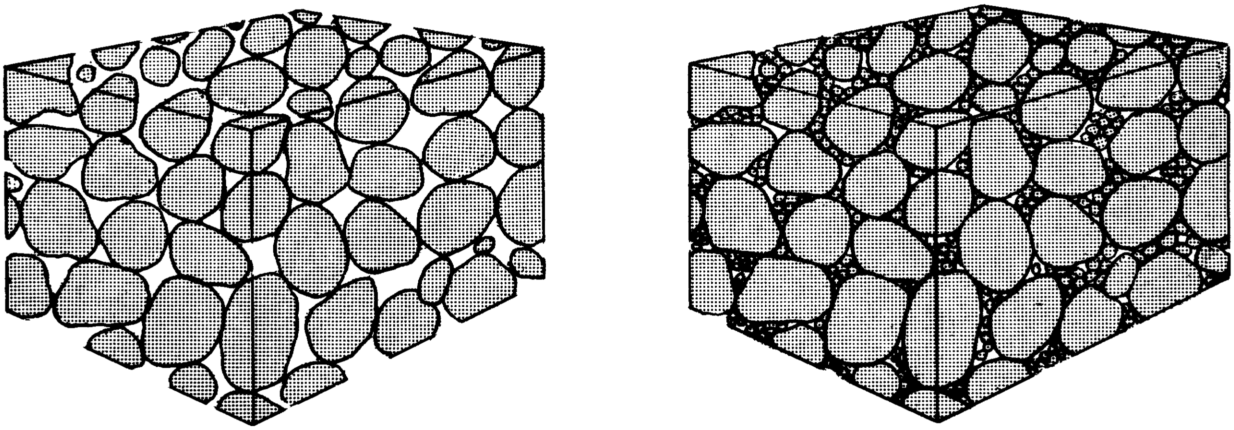
Ground water occurs in the openings between the individual grains or particles that make up the unconsolidated deposits. To illustrate how this works, let's imagine that we have filled a 5-gallon bucket with golf balls. Now we will take several 1-gallon jars filled with water and begin pouring water into the bucket. Even though the bucket is "filled" with golf balls, we find it can still hold between 1 1/2 and 2 gallons of water before overflowing. The exact amount of water that can be held depends on the way the golf balls are arranged. If the balls are haphazardly tumbled into the bucket they will tend to bridge; that is, there will be large openings between some of the balls. By shaking this bucket we can arrange the golf balls more compactly. Now we can put more golf balls, but there is less room for water. In general, material in nature tends to be arranged as compactly as possible.

The amount of water we are able to pour into the bucket is a measure of the porosity of the "deposit" of golf balls. Porosity is defined as the ratio of the volume of openings to total volume of rock and is expressed as a percentage. If, for example, we are able to pour 2 gallons of water into the 5-gallon bucket, we may say that the bucket of golf balls has a porosity of 40 percent (2÷5).

The actual size of the material we put into the bucket will not affect the porosity as long as all the individual particles are the same size and are packed in the same way. A bucket of tennis balls or one of B-B shot will have the same porosity as a bucket of golf balls. If we filled a bucket with golf balls and then mixed in B-B shot, the B-B shot would fill part of the openings between the golf balls. This would decrease the total volume of openings and also reduce the amount of water we could pour into the bucket. Therefore, the better the sorting, that is, the more uniform the size of the particles, the more water that can be stored. This can be seen by comparing the amount of open space shown in the two illustrations in figure 8.

We can imagine a third and even smaller group of particles filling the remaining open spaces between the grains in figure 8-B. If the open spaces were filled with smaller and smaller particles the porosity could easily be reduced to less than 5 percent. Because the particles found in nature have such a large size range, from boulders to microscopic clay particles, there is plenty of opportunity for such filling. Fortunately, many of the unconsolidated deposits in the Eastern Oswego River basin were formed in such a way that their particles are fairly well sorted. The porosity of the unconsolidated deposits ranges from about 10 to 40 percent.

Porosity tells us how much water is stored in a deposit but not how much water can be withdrawn from it. To illustrate the difference between water stored and water available, we can again use the 5-gallon bucket filled with golf balls and water. Let's punch a hole in the bottom of the



A. Well-sorted deposit B. Poorly sorted deposit

Figure 8.--Well-sorted deposits have more open space than poorly sorted deposits.

bucket so that all the water will be able to drain out. If we catch the water that drains and measure it carefully, we will find it is less than 2 gallons we originally put into the bucket. The difference may be about 1 pint. This pint of water is distributed as a thin film around the surface of the golf balls. In other words, the golf balls are wet and cannot be dried by draining alone, just as you cannot shake off all the water on your hands after washing. The water clinging to the surface of the golf balls is called the specific retention and the water that drains is called the specific yield. Together, these two equal the porosity. In our experiment with the golf balls, the porosity was 40 percent, the specific retention was about 2 1/2 percent, and the specific yield (the usable or recoverable storage) was 37 1/2 percent. The relation of porosity to specific retention and specific yield is shown in figure 9.

If we had filled the bucket with B-B shot instead of golf balls, the specific yield would be less even though the porosity would be the same. In other words, although we can pour equal amounts of water into buckets of golf balls and B-B shot, we can drain more water out of the bucket of golf balls. This is because there is less surface area for the water to cling to in the "deposit" of golf balls; every time we double the diameter of the particles we decrease the total surface area of the deposits by about one half. A deposit made up of large particles, therefore, will release a higher percentage of its stored water than a deposit made up of smaller particles. If the deposit has both a high porosity and a high specific yield, it will be an ideal aquifer and pipeline; it will be able to store and transmit large amounts of water.

We have seen, then, that porosity is largely controlled by the uniformity, or degree of sorting of the deposit and specific yield is largely controlled by the size of the particles that make up the deposit. If we classify unconsolidated deposits on the basis of these easily recognized physical features (sorting and particle size) each unit will have distinct water-bearing characteristics.

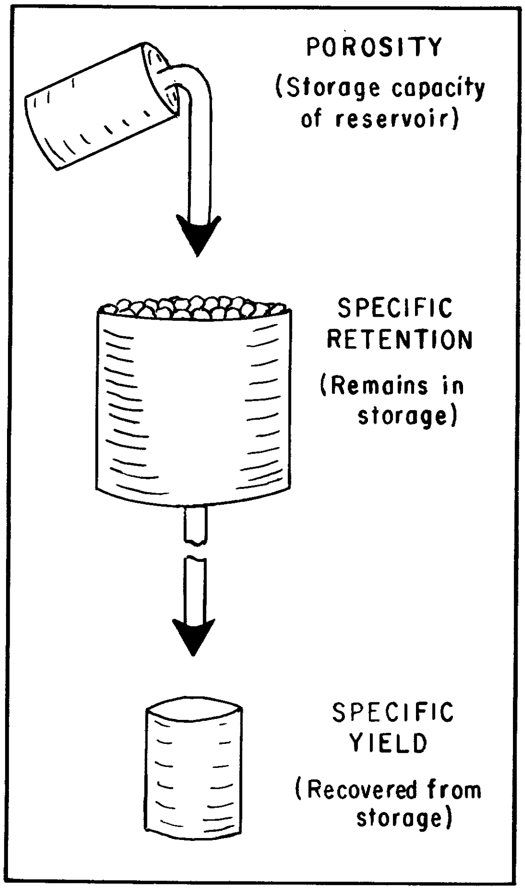


Figure 9.--Not all the water in storage is recoverable.

Unsorted deposits in the basin are referred to as till -- a term originally used in Scotland to describe a mixture of clay, silt, sand, gravel, and boulders. Because till is unsorted it cannot be subdivided on the basis of particle size. Sorted deposits, however, may be conveniently subdivided into clay-, silt-, sand-, and gravel-size particles. In the following sections we will discuss the water-bearing characteristics of the various types of unconsolidated deposits.

More than one unconsolidated deposit may be present at any site; for example, sand may occur beneath clay or gravel may occur beneath till. Plates 1 and 2 are maps of the Eastern Oswego River basin showing only the principal water-bearing deposit present at any site. Also indicated in plates 1 and 2 are the position of the deposits, that is, whether they are at the surface or buried beneath less permeable deposits.

TILL

During the Ice Age massive glaciers moved across the Eastern Oswego River basin from their source in Canada. As the glaciers moved, they picked up parts of the underlying rocks and incorporated them into the ice;

the Finger Lake valleys are impressive evidence of the erosive force of the glaciers. Boulders of Canadian granite that are occasionally found in the basin stand as proof of the glaciers' ability to transport rocks for great distances. Much of the glaciers' rock load, however, was not carried far but rather was crushed and ground up and then laid down as a sort of plaster beneath the ice a short distance from where the rock was first picked up. These deposits of unsorted glacial debris are called till.

A layer of till usually lies directly on the bedrock surface. In many places the till has been covered by other unconsolidated deposits. This is shown in figure 10. Figure 10-A shows typical conditions in the Appalachian and Tug Hill Uplands and figure 10-B represents conditions in the Ontario-Mohawk Lowland. The location of these regions within the basin is shown in figure 2.

The thickness of the till layer in the basin is variable. The till is about 50 feet thick on hilltops, 30 to 40 feet thick on gentle hillsides, and is thinner or may be absent on steeply sloping hillsides. In the Ontario-Mohawk Lowland the till sheet is generally about 30 feet thick but in places may be as much as 200 feet thick. The areas of thickest till accumulation occur as long, sometimes rounded, hills that dot much of the Lowland particularly west of Syracuse. These hills are called drumlins, from the Gaelic "druman" meaning a ridge. Bunker Hill of Revolutionary War fame is probably the world's best known drumlin and Hill Cumorah (in Ontario County, 25 miles west of the Eastern Oswego River basin), where Mormons believe that the Book of Mormon was revealed to Joseph Smith, is New York's most famous drumlin.

Figure 10 shows that drumlins and other relatively high areas of till are not covered by other deposits. In these areas till represents the only unconsolidated deposit present above the bedrock, and for this reason it is shown as the principal water-bearing deposit in plates 1 and 2. Actually, till does not yield water freely. Because of its unsorted nature till has a low porosity; because most of the till is made up of particles of clay and silt the specific yield is also low. Till occurring in the Tug Hill Upland and the northern half of the Ontario-Mohawk Lowland may have a relatively higher specific yield than till found elsewhere in the area. The till in these regions is sandy owing to the underlying sandstone bedrock. Nevertheless, till throughout the basin is generally capable of yielding only a few hundred gallons of water per day to individual wells.

Dug wells are specially suited for the withdrawal of water from till; in fact, they are the only type of well that can supply usable quantities of water from till. A dug well is simply a hole in the ground that extends below the water table into what is called the zone of saturation. All the rock openings in the zone of saturation are filled with water and this water is able to flow into wells. The water table is the upper surface of the zone of saturation; above the water table, rock openings are only partially filled with water and the water cannot flow into wells.

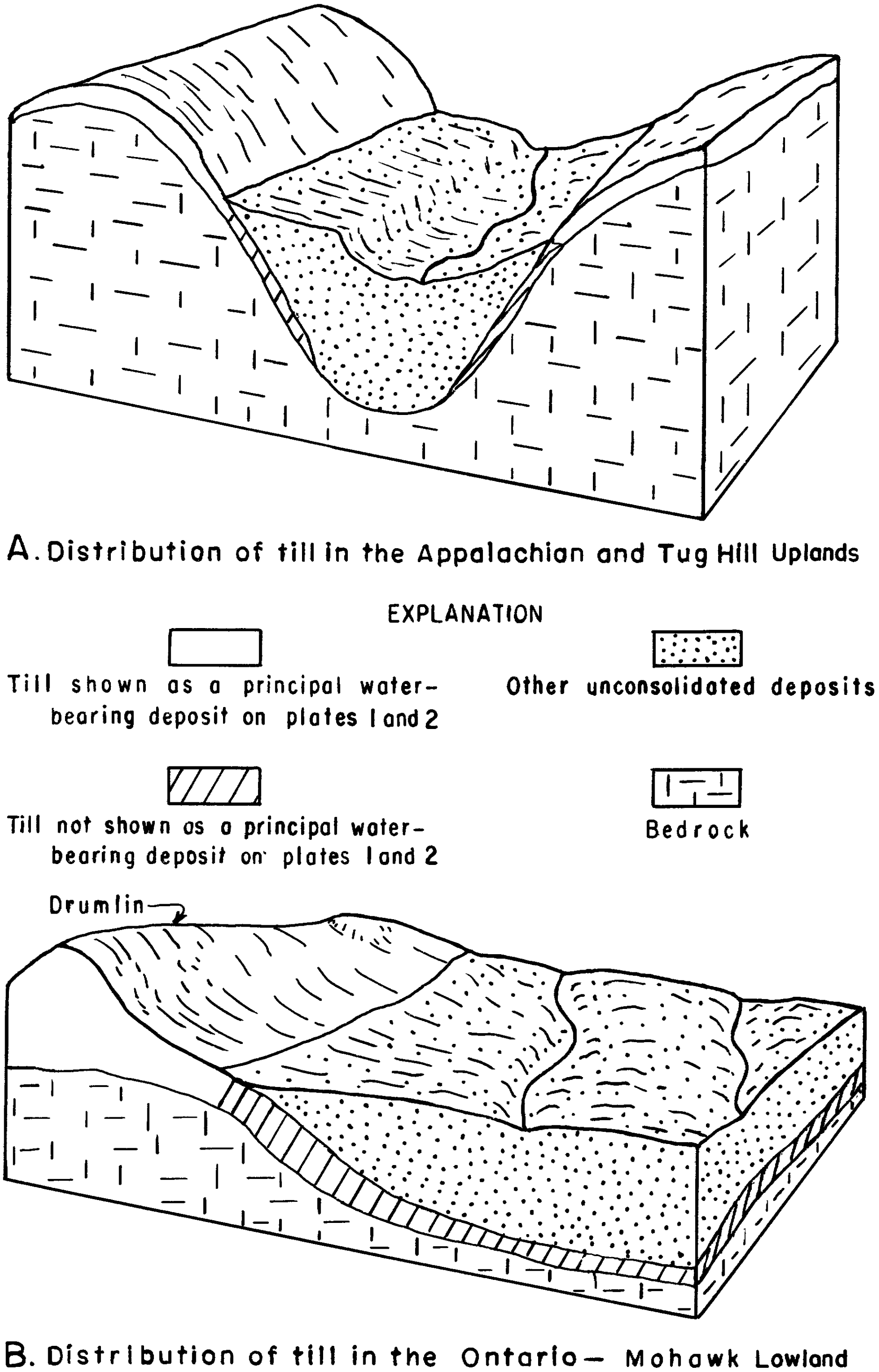


Figure 10.--A layer of till lies directly on the bedrock almost everywhere in the Eastern Oswego River basin.

Dug wells are lined with various sorts of material that keep the sides of the hole from caving in and, at the same time, allow water to enter the hole. The older dug wells were dug by hand and generally lined with large stones. Now most dug wells are dug by power shovels and lined with concrete tiles.

There are two reasons why dug wells in till are successful: the large area from which water can seep into the well, and the well's large storage capacity. A dug well with a 36-inch diameter (the most common diameter) can draw water from almost 10 square feet of till for each foot of depth. Similarly, about 53 gallons of water can be stored in the well for each foot of depth. For example, a 36-inch diameter well extending 10 feet below the water table exposes 95 square feet of water-bearing till and can store about 530 gallons of water. These relationships are shown in figure 11.

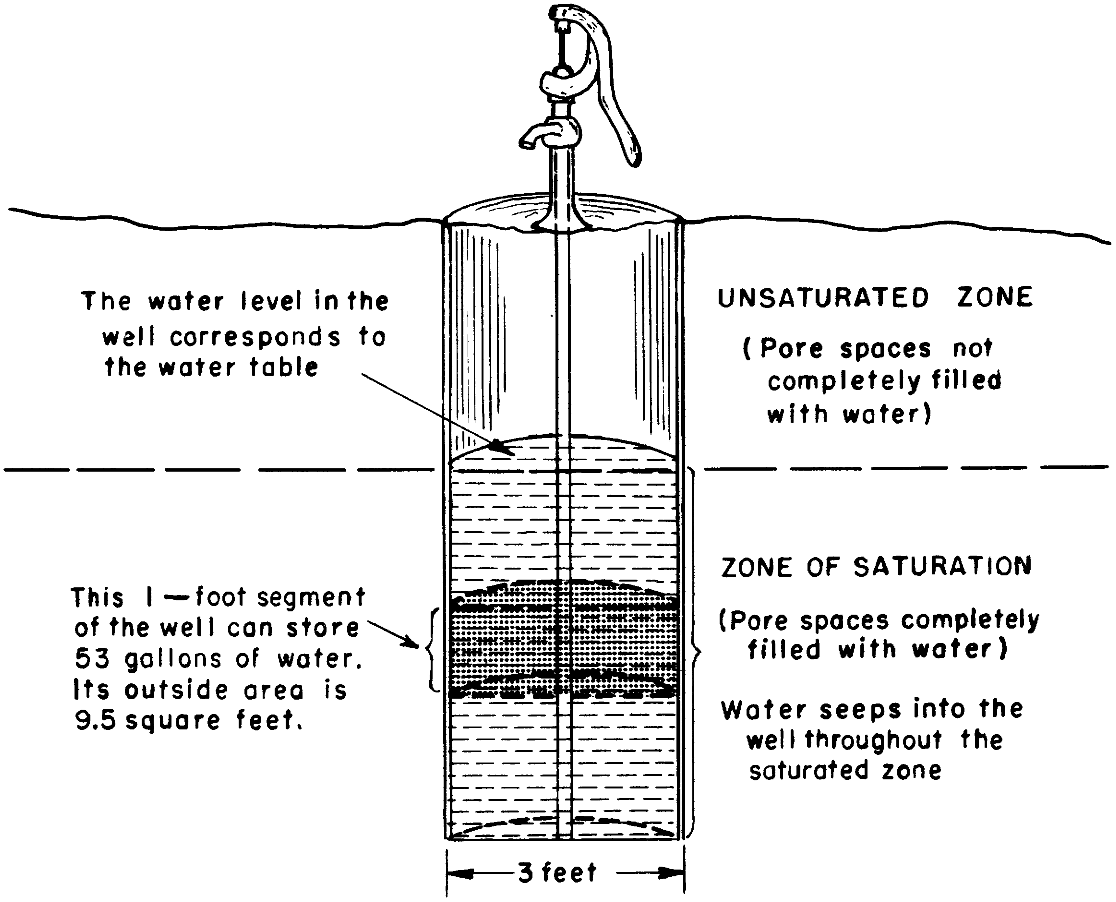


Figure 11.--Dug wells draw water from a large area and have a large storage capacity.

The sustained yield of a dug well is equal to the rate at which water seeps into the well from the till. It depends, therefore, on how much water-saturated till is exposed to the well. Three factors control the amount of till exposed: (1) the depth of the well, (2) the depth to the water table, and (3) the diameter of the well.

Because of their method of construction, dug wells are limited in depth. The deepest dug well measured during field investigations in the basin is 47 feet; the average depth of all dug wells is only 16 feet. The maximum yield of a deeply dug well in till is about 2 gpm and for most wells it is probably less than 0.5 gpm. The large storage capacity of dug wells, however, permits periodic withdrawal of water at a rate greater than its yield. In this way, adequate domestic and farm supplies are obtained from dug wells in many places in the basin. Where the till is not very productive, more than one dug well may be required to supply a farm.

We see from figure 11 that the thickness of water-saturated till penetrated is controlled not only by the depth of the well but also by the depth to the water table. The water table rises and falls during the year and, as we will see in a later section of the report, it is lowest during the summer and early fall. Both the yield and the storage capacity of till wells are reduced when the water table falls. At such times withdrawals from the well may exceed the rate of replenishment. Water levels will be unable to recover between periods of pumping and the well may eventually be pumped dry. Also, the water table may naturally fall until it is below the bottom of the well. The water table in parts of the basin may fall as much as 25 feet between the spring and early fall. When we consider that the average depth of dug wells is 16 feet, we can understand why so many of them go dry.

A study was made of the adequacy of 83 wells dug in till throughout the basin. Of these, only five were completely unable to supply enough water for a domestic supply. However, an additional 31 wells were inadequate during parts of the summer and fall but were satisfactory for the remainder of the year. In other words, about 6 percent of the wells dug in till were inadequate when the water table was high, and about 43 percent were inadequate when the water table was low.

Doubling the diameter of a dug well doubles the area of exposed till. It also increases the storage capacity 4 times and should result in a substantial increase in yield. When yields of more than 500 gpd (gallons per day) are required, as for example on many farms, the advantages of a large (4 to 10 feet) diameter well may outweigh the added construction expenses. Of course, even a large-diameter well will go dry if the water table falls below the bottom of the well, and therefore, the first requirement of a dug well is adequate depth.

Infiltration galleries, or collector wells, are a special type of dug well. These galleries are actually trenches that are as much as several hundred feet long. They are dug in areas where the water table is close to land surface. As shown in figure 12, perforated iron or clay pipe is placed in the trench which is then partly backfilled with gravel. Water is collected all along the trench and commonly drains into a dug well that serves as a storage basin. Infiltration galleries are more elaborate and expensive than dug wells but are used when relatively large supplies of water are required. The villages of Groton and Weedsport each get a part of their water supply from infiltration galleries dug in till. Based on data from the Groton supply, the yield of an infiltration gallery constructed in till may be as much as 2 gallons per hour

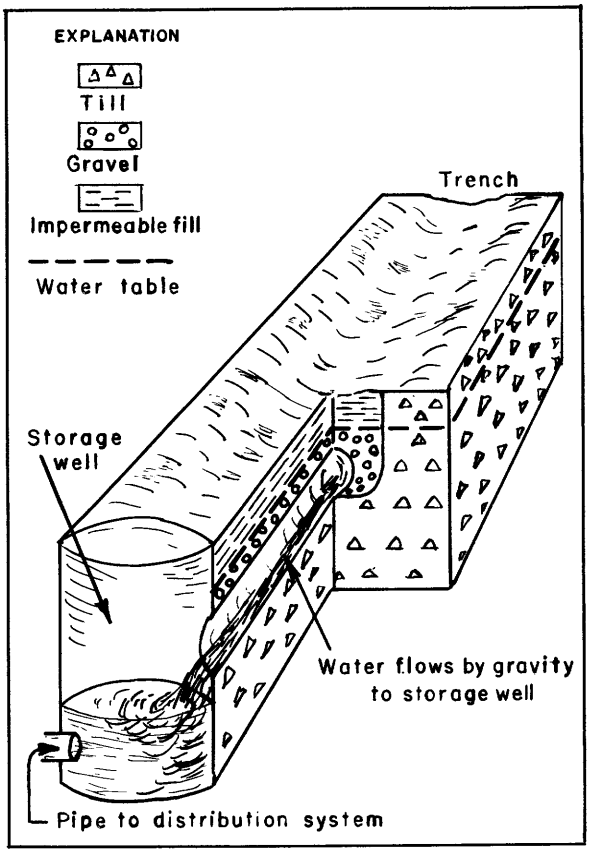


Figure 12.--Infiltration galleries are a special type of dug well that may furnish relatively large ground-water supplies from till.

per linear foot. For example, a gallery 100 feet long may yield almost 5,000 gpd. Of course, water is not used at uniform rates throughout the day so that adequate storage facilities are necessary to make the most efficient use of a gallery.

From what has been said, we can draw the following conclusions about the availability of water from till:

1. Dug wells are the only type of well that can supply usable amounts of water from till;

2. wells in till should be dug as deeply as possible;

3. wells in till should preferably be dug during the time of year when water levels are lowest; and

4. large diameter dug wells or infiltration galleries are the only practical way of obtaining supplies of more than a few hundred gallons per day from till.

If an adequate supply of water cannot be obtained from the till, the only other alternative is to drill a well into the underlying bedrock. A well drilled into bedrock will almost always yield more water and will generally be safer from contamination than a well dug in till -- the combination of shallow well depths and porous well linings make dug wells highly susceptible to contamination. (See the section "Nitrate and pollution.")

SAND AND GRAVEL

We have seen that extensive deposits of unsorted debris (till) were laid down directly by glaciers. Additional unconsolidated deposits were formed as an immense volume of water was released by the slowly melting glacial ice at the end of the Ice Age. This melt water, carrying with it the debris of clay, silt, sand, gravel, and boulders formerly trapped within or carried on the ice, formed rivers and lakes many times larger than those now found in the basin. Deposits laid down by melt water characteristically are sorted and stratified, that is, they occur in layers of similar-sized particles. In general, coarse-grained stratified deposits were laid down by faster moving water in river channels, and deltas, and near-shore areas of lakes. Fine-grained stratified deposits were laid down in the quiet deeper waters of lakes.

Coarse-grained stratified deposits consist of thick layers of well-sorted sand, and thin alternating layers of sand, gravel, and mixtures of sand and gravel. For simplicity we will call these deposits "sand and gravel." The sand grains are usually larger than 0.005 but smaller than 0.08 inch in diameter; it would take between 12 and 200 sand grains laid end to end to equal 1 inch. The gravel is made up of particles larger than sand size but generally smaller than 3 inches in diameter; larger particles up to boulders several feet across are found in some places.

The distribution of sand and gravel in the basin is shown on the maps in plates 1 and 2. We see from these maps that sand and gravel occurs both at the land surface and also buried beneath other unconsolidated deposits. We also see that there are extensive deposits consisting chiefly of sand. The geologic cross sections in plate 6 have been prepared to show the relationship between:

1. Surficial and buried sand and gravel deposits;

2. sand and gravel and the less permeable unconsolidated deposits; and

3. the unconsolidated deposits and the bedrock.

In several places discrepancies may exist between the geologic cross sections and the aquifer maps. These discrepancies result from the difference between the cross sections, which show all the material found beneath each site, and the aquifer maps, which show only the principal water-bearing material. The principal water-bearing material may or may not be exposed at land surface.

Most of the sand and gravel found at land surface was laid down in glacial melt-water rivers. These rivers carried away the debris of clay, silt, sand, and gravel that was held within the ice. Because the velocity of the melt water decreased as it flowed away from the ice, the rivers could no longer carry all the debris. The heaviest material, the sand and gravel, was deposited in the river channels.

The surficial sand and gravel in the Tug Hill Upland and along the southern border of the basin was laid down close to the edge of the glacier. These deposits have an interesting and characteristic appearance. Because the ice margin was badly creviced, masses of stagnant ice commonly became detached. Sand and gravel was deposited around and sometimes over these ice masses. As the ice blocks melted they left depressions called kettle holes in the sand and gravel. The Tully Lakes, about 15 miles south of Syracuse, and Kasoag Lake, 12 miles northwest of Camden, occupy conspicuous kettle holes. At other times, water flowed in tunnels beneath the glacier. Sand and gravel deposited in these tunnels now occurs as sinuous ridges called eskers. Route 13 just north of Westdale follows the crest of one of the largest eskers for more than half a mile. Besides indicating the presence of sand and gravel, kettles and eskers are graphic reminders that glaciers covered the basin only a relatively short time ago.

Other sand and gravel deposits found at land surface were deposited as deltas wherever melt-water rivers entered the temporary lakes that occupied parts of all the valleys in the Appalachian Upland. When the lakes became dry, streams eroded the toe of the deltas until the delta remnants now look like terraces on the sides of the valleys. Figure 15 shows the dissected broad, flat delta occurring as a terrace above West Branch Onondaga Creek near South Onondaga.

Sand and gravel now buried beneath other unconsolidated deposits was laid down in the near-shore areas of lakes or in river channels that were later inundated by lakes. Figure 13 shows a generalized sequence of events typical of the Appalachian Upland in the basin. Melt water from the ice accumulated between the glacier on the north and the bedrock sides and headlands of the north-sloping valleys. The melt water from the ice carried a large amount of rock debris into the lakes. When the melt water entered the lakes, the heaviest particles in the debris, namely sand and gravel, were dropped first, close to the ice. As the melt-water current moved farther out into the lake, its velocity continued to decrease and the sand, the heaviest particles remaining in the load, was dropped. At some point in the lake the incoming water became still and the clay and silt, the light remaining particles, slowly settled to the bottom.

The ice dam in the valleys, that is, the front of the glacial ice, was not stationary but slowly melted back, thus enlarging the lake. Sand and gravel was continuously deposited near the ice front, while the previously deposited sand and gravel was being covered by finer-grained material that settled farther away from the ice. This sequence is shown in the first two diagrams in figure 13. Continued retreat of the ice front down the valleys resulted in the deposition of a continuous layer of buried sand and gravel. This is shown in the third diagram in figure 13.

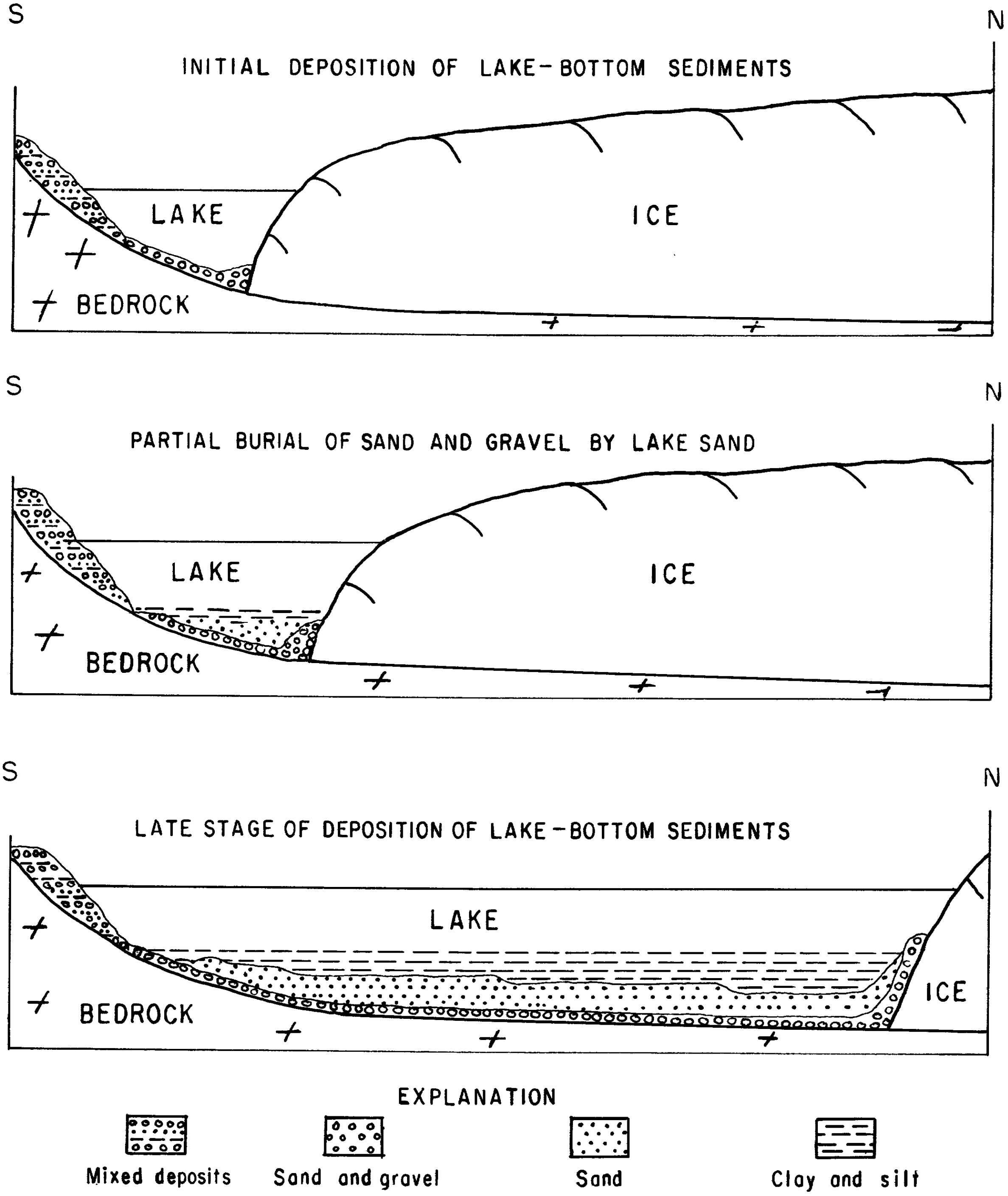


Figure 13.--As the ice melted down the north-sloping valleys in the Appalachian Upland, a thin layer of sand and gravel was deposited and then buried beneath fine-grained lake deposits.

Many of the buried sand and gravel deposits in the Ontario-Mohawk Lowland were doubtless formed in a manner similar to those of the Appalachian Upland. Others, particularly in the southern part of the Lowland, were originally laid down in the channels of melt-water rivers. These rivers most likely flowed eastward and left the present-day basin in the vicinity of Rome. As more and more of the ice melted, the land surface began to rise. The weight of the overlying ice had depressed parts of the basin as much as 400 feet (Fairchild, 1934, p. 242) giving it a northward tilt and now the land was returning to its original position. Uplift of the downstream parts of the melt-water rivers near Rome caused the water to back up, eventually forming a lake that covered almost all of the Lowland. In this way, the river deposits were buried under fine-grained lake sediments.

We see in plate 1 that deposits composed chiefly of sand are extensive over much of the Ontario-Mohawk Lowland. These deposits are distinguished from sand and gravel in plates 1 and 2 because, as we will see later, the nature of the wells tapping them and their yield differs from those of the gravel-bearing deposits.

We know that the unconsolidated deposits were derived from rock debris held in the Ice-Age glacier. The debris, in turn, was supplied by the bedrock over which the ice moved. The abundance of sand, or rather, the absence of gravel-sized particles, in the unconsolidated deposits found in the northern part of the basin reflects the fact that much of the underlying bedrock is sandstone. The ice broke the sandstone down into individual particles of sand. The predominant grain size of the sand deposits, from about 0.005 to 0.01 inch in diameter, thus reflects the grain size of the sandstone bedrock.

Most of the sand deposits originated in the same way as the sand and gravel deposits, that is, as river-channel, deltaic, and lake deposits. However, the ice in the northern part of the basin contained so little silt and clay and relatively few large fragments that even the till is predominantly sand, in fact, many of the deposits north of Fulton that are mapped as sand in plate 1 are actually till.

Deposits of gravel-free sand also occur in areas other than those shown in plates 1 and 2. The most extensive of these areas is the region between Oneida Lake and Rome known as the Rome Sand Plains. The distribution of surficial sand in this area is shown in figure 14. Much of the sand plains is underlain by a preglacial valley that is now partially filled with sand and gravel.

Wherever the sand and gravel deposit is present, it is mapped as the major aquifer in plate 1. Nevertheless, the surficial sand is an important source of water for domestic and farm supplies. Other sand deposits, not mapped as major aquifers, overlie many of the buried sand and gravel deposits shown in plates 1 and 2. The origin of these sand deposits is illustrated in figure 13. They are unimportant as aquifers because they are relatively thin and are found together with more permeable gravel-bearing deposits.

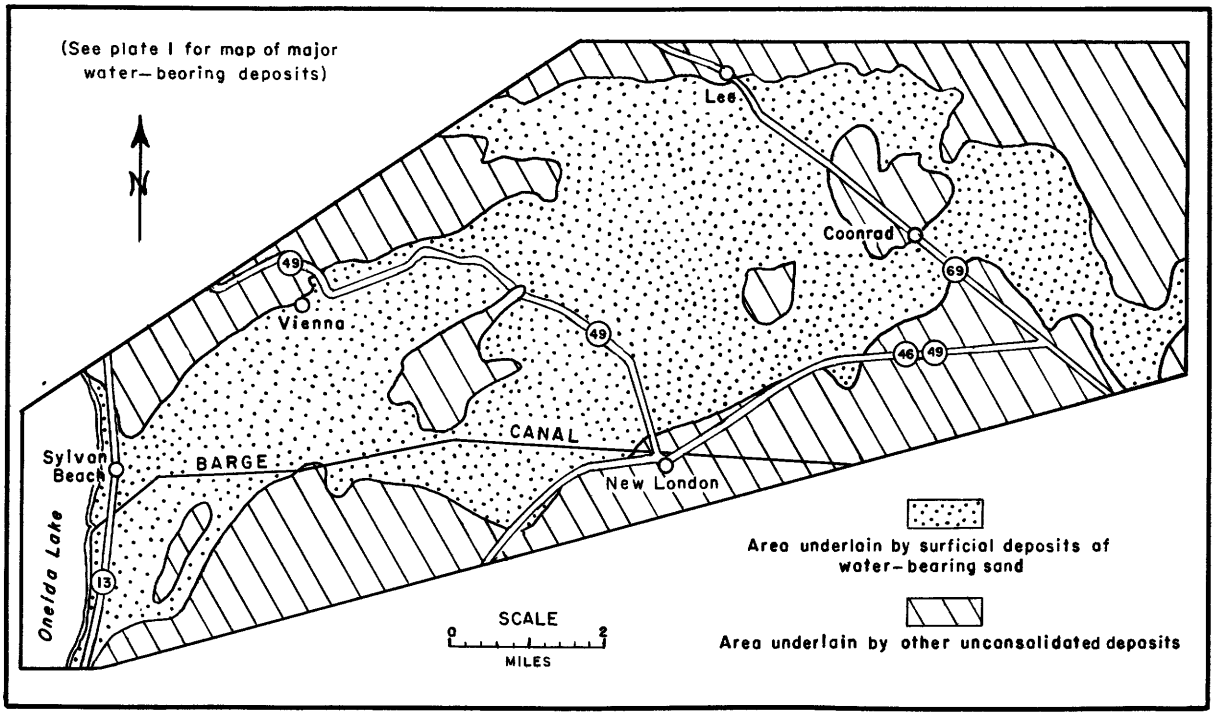


Figure 14.--Map of the Rome Sand Plains showing the extent of water-bearing surficial sand deposits.

Occurrence of ground water

Deposits of sand and gravel in the basin are relatively well sorted and have a high porosity, generally between 20 and 30 percent. Some individual layers of rounded, very well sorted sand or gravel may have a porosity of as much as 40 percent. We have seen, however, that the specific yield of a deposit, that is, the percentage of stored water that can be released by draining, determines its worth as an aquifer. The larger the size of the particles making up a deposit, the higher its specific yield. Therefore, a deposit made up chiefly of sand-size particles will have a relatively low specific yield and a deposit made up chiefly of gravel-size particles will have a relatively high specific yield. In general, sand and gravel has the capacity to store large amounts of water and a high percentage of this stored water can be withdrawn. Sand and gravel is, in fact, the best water-yielding material in the Eastern Oswego River basin.

Water in surficial sand and gravel aquifers is under water-table conditions; the water level in wells corresponds to the upper limit of saturation in the deposit. This has been shown diagrammatically in figure 11. As a general rule-of-thumb, wells in surficial sand and gravel aquifers should extend at least down to the level of the bottom of the nearest stream, and preferably deeper. If the stream is known to go dry during

the summer months, the well should be considerably deeper. If this rule is followed, the well will generally be productive even during dry periods. In some areas wells must be drilled through almost 200 feet of dry sand and gravel before the water-bearing zone is reached. The occurrence of ground water in one such area (near South Onondaga) is shown in figure 15.

Figure 15 also illustrates another interesting feature. Sand and gravel is found at land surface near well 254-611-1. However, this sand and gravel deposit is completely dry and the water table occurs in the underlying bedrock. The sand and gravel deposit is, therefore, not shown as an aquifer in plate 2.

Test borings have shown that fine-grained material (clay and silt) is present in some of the surficial sand and gravel deposits. These fine-grained layers and lenses were probably deposited in the quiet water of temporary lakes and were later buried by sand and gravel. Where fine-grained, relatively impermeable layers occur within the unsaturated zone, a peculiar condition known as perched water may exist. As shown in figure 16, a small isolated water table may be "perched" above the main water table. Rainfall or snowmelt that seeps into the sand and gravel at land surface usually moves down into the saturated zone. However, if this water meets an impermeable layer of fine-grained material it will accumulate above it. Perched-water bodies are unreliable sources of water because they easily can be pumped dry or else they may dry up naturally during the summer. Perched water can be avoided by constructing wells deep enough to be at or below the nearest stream bottom.

Wherever streams or rivers flow across surficial sand and gravel deposits, the potential for a large ground-water supply exists. Ordinarily, the water table in the aquifer is higher than the water level in the stream. This means that water moves from the aquifer into the stream. The water withdrawn from an aquifer by a pumping well causes the water table to be lowered. If enough water is withdrawn, the water table may become lower than the water level in the stream. This reverses the normal pattern of flow and causes water to move from the stream into the aquifer. This is called an infiltration supply and is illustrated in figure 17. The yield of an infiltration supply is limited only by the amount of water in the stream and the "pipeline" capacity (permeability) of the aquifer. Areas where stream infiltration is believed possible are shown in plates 1 and 2.

Water in buried sand and gravel aquifers is generally under artesian pressure. Pressure builds up in the aquifer because the water entering at a higher altitude cannot rise through the overlying fine-grained material to seek its own level. Water in wells drilled into buried sand and gravel aquifers will rise above the top of the aquifer, just as water from a pressure tank wil rise above the level of the tank when a tap is opened. The level to which water rises in a well penetrating an artesian aquifer is called the piezometric surface. When the piezometric surface is above the land surface, artesian wells will flow but whether the piezometric surface is above land surface or below (in which case, the well will not flow) the well is artesian. The mechanics of artesian aquifers are illustrated in figure 18 by means of an analogy with a

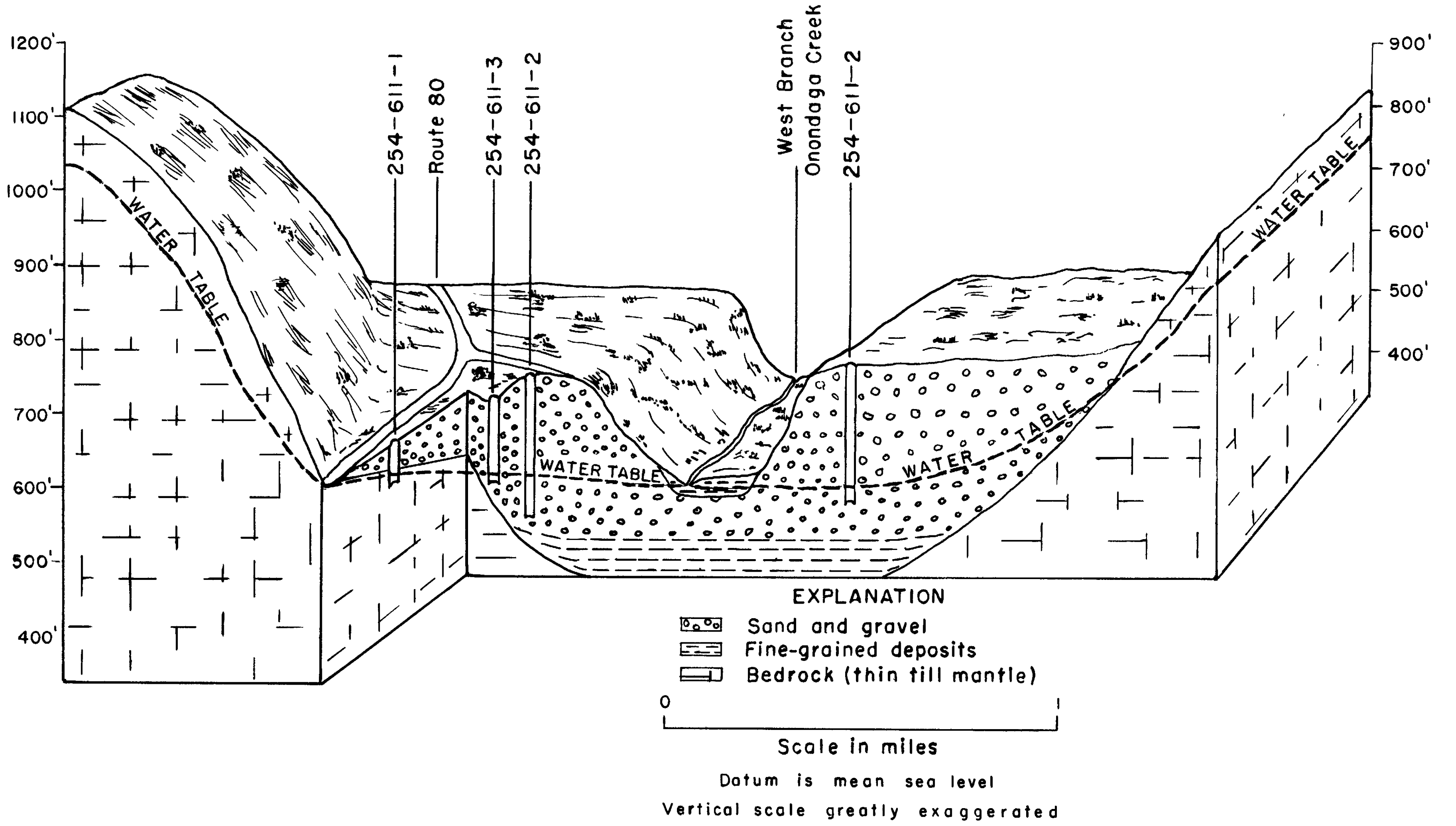


Figure 15.--Wells in surficial sand and gravel deposits should be drilled or dug below the level of the nearest stream.

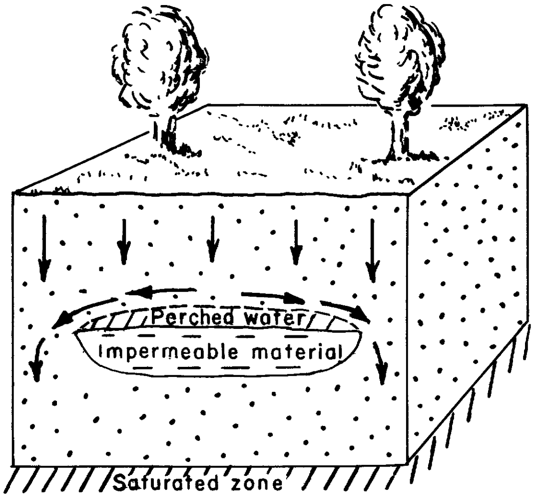


Figure 16.--Water in the unsaturated zone may accumulate above an impermeable layer to form a perched water table. (Arrows indicate direction of water movement.)

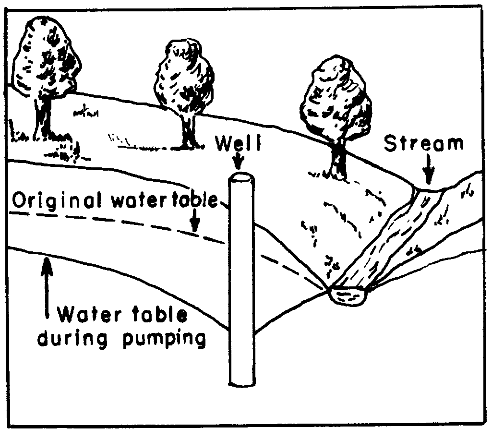


Figure 17.--Wells located near a stream may induce infiltration of water from the stream into the aquifer.

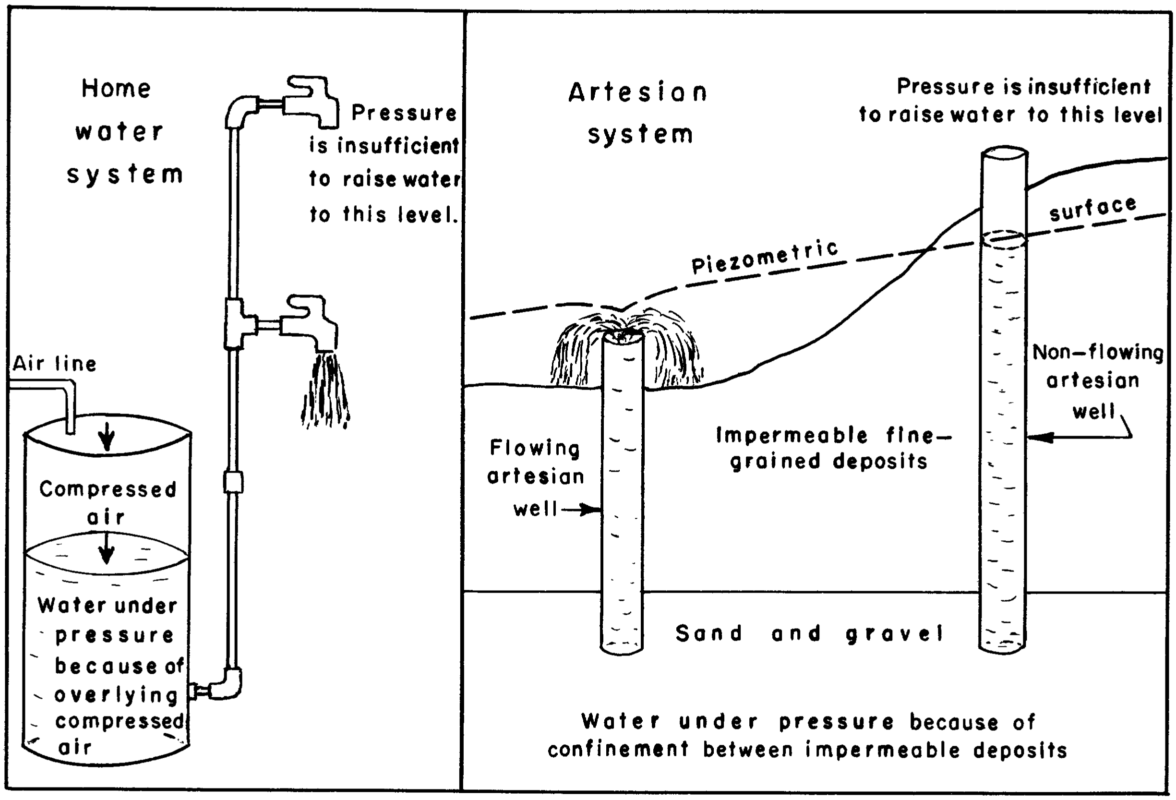


Figure 18.--The mechanics of artesian aquifers are similar to those of home water systems.

pressure tank in a home water system. We can see from this diagram that the height to which water in a well will rise is controlled by the position of the piezometric surface, not by the amount of penetration into the aquifer.

The quality of water in some of the buried sand and gravel aquifers is poor and the water may be unsuitable for many uses. Areas where salt water is known or is likely to occur are shown in plates 1 and 2. The quality of ground water in the basin is discussed in some detail later in this report.

Wells

Sand and gravel will yield water freely to all the common types of wells. The choice of the type of well to use depends on how much water is wanted, the position of the aquifer (surficial or buried), the nature of the aquifer (gravel bearing or gravel free), and economic considerations.

Drilled wells.--Drilled wells may be constructed by any of several methods; however, the only one used extensively in the basin is the cable-tool method. In cable-tool drilling a bit is pounded against the earth material and the crushed or loosened material is removed from the hole by bailing. The diameter of the hole is determined by the diameter of the drill bit. The most common diameter is 6 inches. Larger diameter wells are drilled when relatively large amounts of water are needed. The increase in entrance area yields a little more water but, more importantly, the larger diameter permits the placement of a bigger pump. The most obvious advantage of drilled wells is the great depth to which they can be drilled. Because of this they are particularly suited to tapping sand and gravel deposits that are buried beneath less permeable deposits.

There are two basic types of drilled wells -- open-hole wells and screened wells. All the drilled wells used for domestic and farm supplies in the basin are of the open-hole type. In this type of well the hole is cased off as drilling progresses; that is, pipe is installed in the hole to prevent caving. When the well penetrates a satisfactory water-bearing layer of sand and gravel, drilling is stopped. The tubular well casing extends all the way to the bottom of the hole; only the end of the casing at the bottom of the well is exposed to the sand and gravel. This means that a 6-inch diameter well has an exposed area of about 28 square inches (less than one-fifth of a square foot). Sand and gravel is so permeable that, as shown in figure 19, the median yield of 96 open-hole wells in sand and gravel is 15 gpm; that is, the yield of half the wells is less than 15 gpm and the yield of the other half is more than 15 gpm.

Several factors combine to cause the variation in the yield of open-hole wells as shown in figure 19. Probably the most important is the way the yields were determined. For the most part, the higher values represent the maximum possible yield measured by the driller. Most yields less than about 10 gpm represent the rates at which the wells are pumped when in actual use. Other factors affecting well yields are the ability of the sand and gravel to transmit water and the amount of available drawdown in the well. Available drawdown refers to the maximum the water level in a well can be lowered by pumping. Most open-hole wells can probably yield at least 2 gpm per foot of drawdown.

In water-table aquifers the available drawdown can be increased by drilling as deeply into the zone of saturation as possible. The available drawdown in wells tapping artesian aquifers is controlled by the altitude of the piezometric surface and is relatively constant at each site. Of course, maximum drawdown in any well is obtained by setting the pump or pump intake as deep as possible.

An open-hole well in sand and gravel generally requires some development, that is, treatment to increase their yield and to obtain sand-free water. The most widespread type of well development is based on the physical laws that govern the transport of sediment: the faster water is moving, the larger and heavier the particles it can carry. Initially, water pumped from a well will probably contain some sand because the velocity of the water entering the well from the sand and gravel aquifer is sufficient to raise the smaller, lighter sand and silt particles.

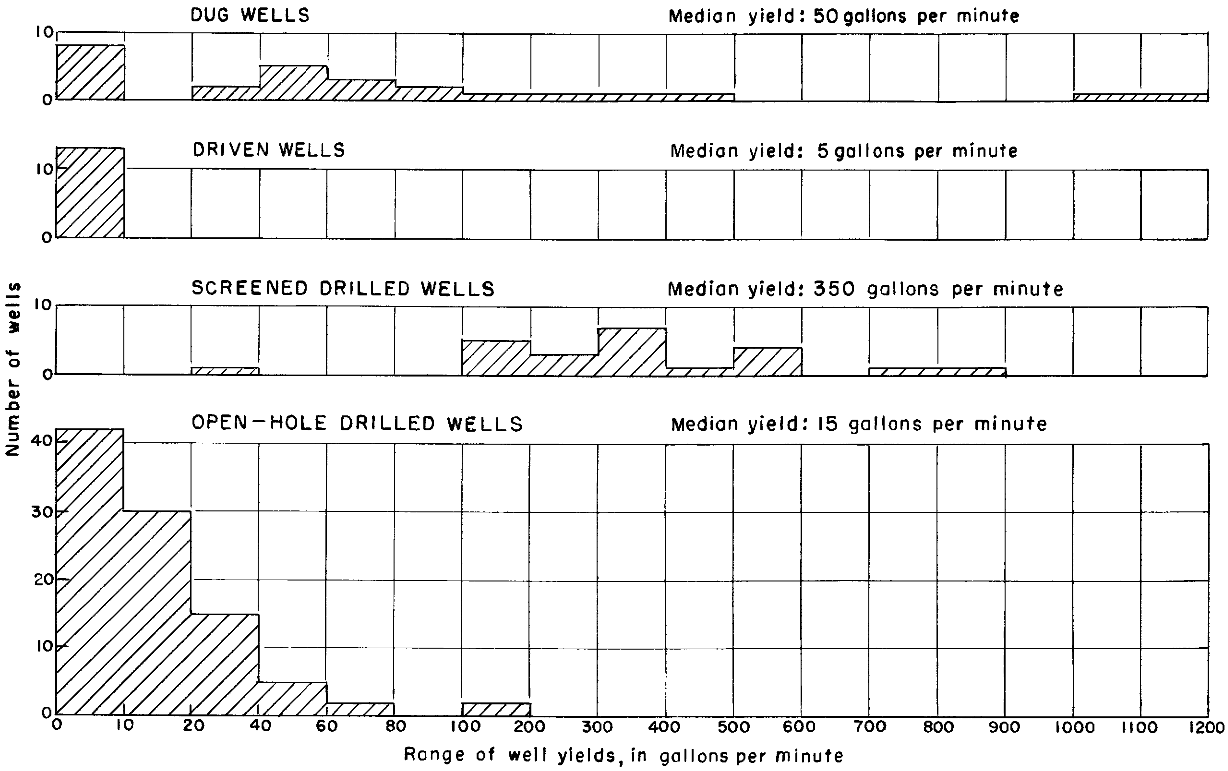


Figure 19.--The yield of sand and gravel wells is related to the manner of their construction.

When the well is completed, the driller will usually pump or bail the well at its maximum capacity. This produces a maximum water velocity, and the smaller particles around the open end of the well are pumped or bailed out. As shown in figure 20 a gravel or relatively coarse sand pack will form around the open end of the casing. If, when put into normal use, the well is pumped at a lower rate than it was during development, the velocity of the water in the well will generally be too slow to raise the larger size sand grains remaining in the sand or gravel pack.

Development by overpumping will be unsuccessful if the aquifer does not contain enough coarse-grained material to create the natural pack. This is often the case with open-hole wells drilled into the sand aquifers shown in plates 1 and 2. About 7 out of every 10 wells drilled into these aquifers yield water containing suspended sand particles. Wherever the aquifer is fine grained, coarse-grained material may be poured into the well to create an artificial sand pack. This is illustrated in figure 21. Although basically correct in theory, the material used for the artificial pack must be chosen with care to insure success. In the Eastern Oswego River basin gravel-sized particles (about a tenth of an inch or larger) are commonly used for pack material. Sand in the aquifer often

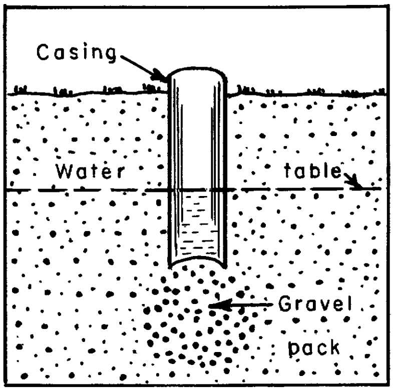


Figure 20.--Overpumping an open-hole well may create a natural sand or gravel pack around the open end of the casing.

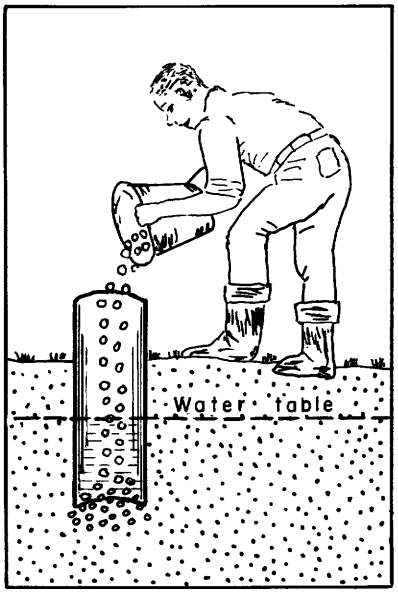


Figure 21.--Sand aquifers may be stabilized by creating an artificial coarse-grained pack within the well casing.

works its way into the relatively large openings between the gravel particles. When this happens, the well will again produce sandy water. To prevent clogging of the openings in the artificial pack, the pack material should be only about 5 times larger than the average size of the aquifer material. For the sand aquifers shown in plates 1 and 2 the most effective pack material would be a sand with an average grain diameter of about 0.025 inch (1/40 of an inch). In no case should the sand-pack material have a diameter larger than 0.05 inch.

Another way to obtain sand-free water is to decrease the velocity of water in the well. Almost all the drilled wells in the basin are constructed with 6-inch diameter casings and are intermittently pumped at rates of about 5 gpm. This means that the velocity of the water in the well is at least 0.057 foot per second -- sufficient to raise enough sand to create a serious problem. The velocity can be decreased by pumping at a lower rate. For example, pumping a 6-inch diameter well at a rate of 2 gpm produces a velocity of only 0.023 foot per second -- probably slow enough in most cases to produce a sand-free supply. Such a pumping rate may be too low for some users. A similar velocity, however, would result from the pumping of an 8-inch diameter well at 5 gpm.

Without extensive well development, it probably is not possible to pump sand-free water from 6-inch diameter open-end wells at rates of more than about 30 gpm. Larger diameter wells, however, will yield sand-free water at higher pumping rates.

The other type of drilled well is the screened well. Screened wells are drilled in the same manner as open-hole wells but are finished with a well screen or "strainer" at the end. Slotted or perforated pipe is sometimes used in place of a screen but is generally less effective. Once a suitable thickness of water-bearing sand and gravel is penetrated by the drill hole, a length of screened pipe is lowered to the bottom of the casing; the casing is then pulled back and the screen is exposed to the sand and gravel. As shown in figure 19, screened wells almost always yield more water than open-hole wells. The reason for this is the larger open area of the well that is in contact with the sand and gravel, and the great increase in permeability created in the aquifer around the screen during development. Because the fine particles can be completely removed from around the screen withdrawal of sand-free water at high rates of discharge is possible.

In most instances, the openings in the well screen should be large enough to allow about 50 percent of the aquifer material to pass into the well. A grain-size analysis should be made to determine the 50-percent value. Screened wells should be developed by moving water back and forth through the screen. This is called surging and can be accomplished by lowering and raising a piston-like device called a surge-block in the well, by the use of compressed air or dry ice (frozen carbon dioxide) which acts as an air lift and ejects water violently from the well, or by alternately jetting water into the well and then pumping it out. Surging removes the fine-grained particles adjacent to the screen and creates a natural sand or gravel pack from the remaining relatively coarse particles.

Screened wells are often more efficient when installed with an artificial sand or gravel pack. In particular, the finer, sand aquifers shown in plates 1 and 2 are best developed by means of this type of well. A screened well with an artificial sand pack, such as the one shown in figure 22 is most commonly constructed by:

1. Drilling a large-diameter hole and casing it to the bottom;

2. installing a smaller-diameter screened casing inside the larger casing;

3. pouring enough sand-pack material into the area between the two casings to cover the screen;

4. filling the remainder of the area between the casings with an impermeable material; and

5. pulling back the outer casing above the screen, or completely removing the outer casing.

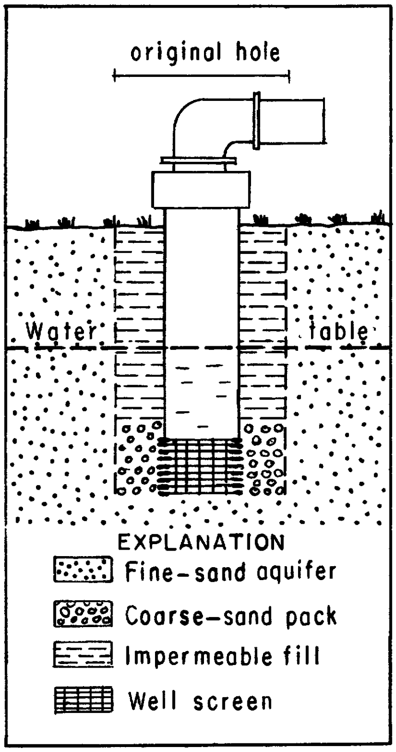


Figure 22.--A screened well with an artificial sand pack is an effective way of obtaining sand-free water.

The sand-pack material should be about 5 times larger than the aquifer material and the screen openings should be approximately the same size as the smallest particles in the sand pack. Sand-packed screened wells are developed by surging, although less development is needed than in ordinary screened wells.

Screened wells, with or without an artificial sand pack, are more expensive than open-hole wells. In the Eastern Oswego River basin they have been used only for industrial and public supplies. Screened wells are necessary for domestic or farm supplies only if a permanently sand-free supply sufficient for all needs cannot be obtained from an open-hole well.

Driven wells.--Under certain conditions driven wells are an economical way of obtaining water from sand and gravel. This type of well is constructed by manually or mechanically pounding (driving) a pipe into the ground. The diameter of the pipe is commonly 1 1/4 inches but may be as much as 2 inches. A drive point is almost always attached to the lower end of the pipe and the tapered end of the point allows the pipe to penetrate the sand and gravel. Gravel larger than about 1 inch in diameter will probably make driving difficult; gravel larger than 3 or 4 inches in diameter will probably prevent effective driving. The depth to which wells may be driven is limited by the friction of the deposit against the pipe and point. Because this friction increases with depth, wells are rarely driven more than 50 feet and most are about 20 feet in depth.

The part of the drive point above the tapered end serves as a well screen and is constructed in such a way that sand particles are held back while water is allowed to flow into the well. Relatively large perforations or slots are cut into the drive unit above the point and are covered by a fine wire gauze. The size of the openings in the gauze should be chosen on the same basis as the openings in a well screen, that is, they should be large enough to allow about 50 percent of the sand in the aquifer to pass into the well. Driven wells in the coarser sand and gravel deposits should probably have a screen opening of about 0.01 inch. Well points with this opening are sold commercially as "Number 60 Gauze" points. Driven wells in the deposits consisting chiefly of sand should have openings of 0.006 inch ("Number 90 Gauze").

Driven wells, like screened drilled wells, should be developed by surging to create a natural sand pack around the well point. The compressed air and jetting-pumping methods of surging are best suited to driven wells. Driven wells should not be developed by overpumping; the fine particles in the aquifer may clog the screen openings.

Because of their small diameter, most driven wells are in contact with less of the aquifer than are open-end drilled wells. Less than half of a drive point is actually open space -- a 3-foot well point, 1 1/4 inches in diameter, has a maximum open area of only about 7 square inches. This compares to an open area of 28 square inches exposed in a 6-inch diameter open-end drilled well. This difference is reflected in the lower yields of driven wells as shown in figure 19.

Also, because of their small diameter, driven wells can generally be pumped only by direct suction (hand pumps or centrifugal pumps). This means that the water level in the well must be less than 25 feet below the

pump, within the practical limits of suction. Thus, the use of driven wells is limited to areas where both the sand and gravel and the water table are found relatively close to land surface.

Dug wells.--The other common type of well used to obtain water from sand and gravel is the dug well. We have already looked at the features of dug wells in the section on till. The most important features of these wells, in regard to sand and gravel, are the large areas of the aquifer they expose and their limited depth. Because they draw water from such large areas, dug wells generally have a higher yield than open-hole drilled wells (fig. 19). The yield of the wells increases with their diameter. Wherever practical, infiltration galleries (fig. 12) would also be highly effective in sand and gravel aquifers.

Because of the large storage capacity and large diameter of dug wells, water enters at relatively low velocities. This means that sand generally is not pumped except when the intake pipe is placed too close to the sandy bottom of the well. A fine-gauze strainer can be placed on the end of the intake pipe to filter out sand. When dug wells are constructed in deposits consisting chiefly of sand, it is advisable to place a coarse sand pack around the lower part of the well (outside the casing) and on the bottom of the well (inside the casing). This is shown in figure 23. The sand-pack material should be about five times larger than the aquifer material.

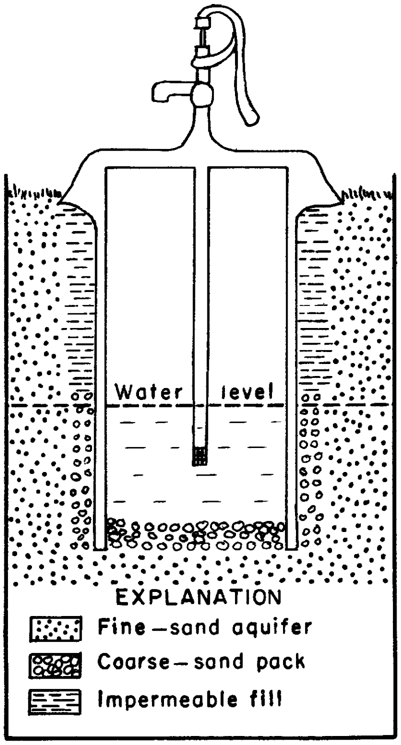


Figure 23.--Sand-free water can generally be obtained from a dug well with a coarse sand pack.

Dug wells in sand and gravel serve as public-supply wells in several villages and communities in the basin including Baldwinsville, Central Square, and Manlius. These wells are as much as 20 feet in diameter, and some of them yield more than 1,000 gpm.

CLAY AND SILT

Deposits of clay and silt were laid down in the quiet waters of lakes that once covered much of the basin. These lakes were so extensive that, except for till, clay and silt is the most widespread of all the unconsolidated deposits. In previous sections of this report we have seen that clay and silt is often found together with layers of sand and gravel (fig. 13). The deposits designated as buried sand and gravel, as shown in plates 1 and 2, are overlain by clay and silt. Wherever this occurs the clay and silt is not considered to be a source of water. In these paragraphs we are concerned with the deposits shown as clay and silt in plates 1 and 2. These deposits are labeled "water-bearing material" but it is a title won by default; wherever clay and silt is designated on the maps, it is the only unconsolidated deposit present.

Clay and silt deposits consist of microscopic particles smaller than 0.003 inch in diameter; it would take more than 300 of the largest silt particles or more than 6,000 of the largest clay particles laid end to end to equal 1 inch. Although silt particles may be more than 20 times larger than clay particles, the two are almost always found together in nature: as a succession of thin, well sorted layers; as silt with some scattered clay; or as clay with some scattered silt.

Deposits of clay and silt are very porous. In fact, clay and silt can store more water than any other material found in the basin. The water-bearing openings between individual grains are so small, however, that the specific retention of the deposits is almost equal to the porosity. Virtually all the water stored in clay and silt is held as a tight film around the particles. Clay and silt is therefore the poorest source of ground water in the basin. Because it is virtually impermeable, clay and silt act as a confining layer for underlying aquifers (fig. 18). This is the reason that artesian conditions occur in all the buried aquifers shown in plates 1 and 2.

There is no known instance of drilled or driven wells ever supplying usable quantities of water from clay and silt. Dug wells can generally supply minimum quantities of water, doubtless not more than 100 gpd in most cases. Much of this water probably enters the wells from paper-thin layers of very fine sand occurring throughout most clay and silt deposits. More than half the dug wells in clay and silt observed in the basin are inadequate during periods when the water table is low. As with similar type wells in other deposits, dug wells should be as deep as possible. In order that they always have water, dug wells should be constructed in the summer or early fall when water levels are lowest and the wells can be dug the deepest.

Deposits of clay and silt furnish, at best, only marginal supplies of water. It is, therefore, advisable to obtain water from a more reliable source. In areas where clay and silt is the only unconsolidated deposit present (pls. 1 and 2) the underlying bedrock may supply adequate quantities of water.

MIXED DEPOSITS

Mixed deposits, as their name implies, are a mixture of all the types of unconsolidated deposits we have discussed so far. That is, they are composed of layers of till, sand and gravel, sand, and clay and silt that occur in an irregular sequence. Mixed deposits were formed whenever the front of the Ice-Age glaciers remained stationary for relatively long periods of time. During these periods the ice continued to move forward but increased melting held the ice front at a constant position. This meant that debris-laden ice was always moving toward the region of melting. Drainage conditions and rates of melt-water flow were variable; at times melt-water rivers deposited layers of sand and gravel or sand and at other times sand or clay and silt was laid down in temporary lakes. Layers of till, marking temporary advances of the ice, are also found in mixed deposits.

The distribution of mixed deposits in the basin is shown in plates 1 and 2. Mixed deposits are found at the southern end of all the major valleys in the Appalachian Upland (pl. 2). These deposits are called the Valley Heads Moraine by most geologists; they are also called the Tully Moraine because they are most strikingly developed at the head-waters of Onondaga Creek in the town of Tully. The Valley Heads Moraine is the thickest accumulation of mixed deposits in the basin; in places, more than 500 feet of mixed deposits are found. Less extensive accumulations of mixed deposits also occur in the Appalachian Upland north of the Valley Heads Moraine; they mark shorter but significant stationary periods during the retreat of the ice. Extensive mixed deposits, generally less than 100 feet thick, are found in and around the Tug Hill Upland (pl. 1). They occur in concentric bands marking successive positions of the ice as it melted back from the highlands.

We have already seen that sand and gravel is the best water-bearing material in the basin. Fortunately, layers of sand and gravel are almost always present within mixed deposits. Wells drilled into these layers are the most reliable sources of water from mixed deposits; they are adequate sources for domestic and farm supplies and may furnish enough water for moderately large public and industrial supplies. Highest yields (up to 350 gpm) are to be expected in the Appalachian Upland (pl. 2) where the mixed deposits are thickest and the gravel content is the greatest. Elsewhere, yields may be as much as 100 or 200 gpm. Development of drilled wells in the sand and gravel layers within the mixed deposits should follow the suggestions made in previous sections of this report. Doubtless, there are some areas where the mixed deposits contain little or no sand and gravel. In these areas till or the underlying bedrock will be the most reliable source of water.

Artesian conditions are common in mixed deposits wherever a permeable water-bearing layer lies beneath an impermeable layer. This situation is illustrated in figure 24. Many deeply drilled wells in mixed deposits

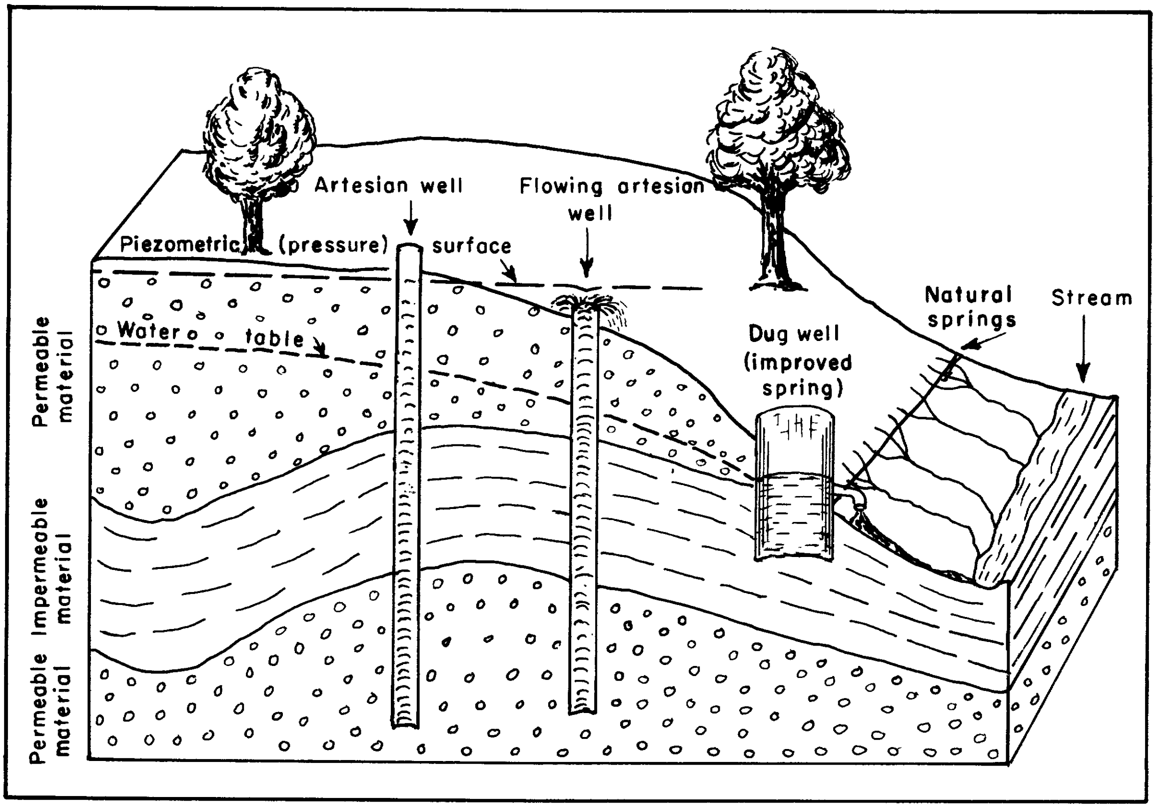


Figure 24.--Both springs and artesian wells are common in areas underlain by mixed deposits.

flow at the land surface, although as we see in figure 24, not all artesian wells necessarily flow. Figure 24 also shows us that not all flowing wells are artesian. Sand and gravel often overlies clay and silt or till within mixed deposits. Such conditions are often favorable for the formation of springs. Ground water in the permeable layer cannot drain downward freely and tends to accumulate above the contact with the impermeable layer as shown in figure 24. Wherever the contact is exposed at land surface it is commonly marked by a line of springs or seeps. Such springs are easily developed by means of shallow dug wells. The flow of the springs almost always is reduced in the summer and early fall when the water stored in the permeable layer is depleted. Even so, many springs in mixed deposits are sources of adequate year-round domestic and farm supplies.

WATER IN THE BEDROCK

Bedrock, or consolidated rock, underlies the entire basin. We see the bedrock in some road cuts and in stone quarries, and in natural

exposures, such as stream channels. Elsewhere, the bedrock is buried by as much as several hundred feet of unconsolidated deposits. Compared to the unconsolidated deposits, bedrock has relatively uniform physical and water-bearing properties. Nevertheless, differences exist between the various types of bedrock. Geologists have subdivided the bedrock in the basin into 16 major units according to age -- the stage of the earth's history during which the rocks were formed -- and according to physical properties -- whether the rocks are composed of shale, sandstone, or carbonates (limestone and dolomite). Ground-water users find the physical properties important because such properties strongly affect the water-bearing characteristics of bedrock. As shown in table 3, we can reduce the 16 rock units to 7 water-bearing units by grouping some formations of different geologic age; for those who are interested, all the bedrock in the basin was formed between about 350 and 500 million years ago during the Devonian, Silurian, and Ordovician geologic periods. Some data on well yields from bedrock are also shown in table 3. Generally speaking, bedrock is a better source of water than till or clay and silt, but a poorer source than either sand and gravel or mixed deposits.

The distribution of the bedrock water-bearing units is shown in plates 3 and 4. These maps show the rocks that would appear at land surface if all unconsolidated deposits were removed. The bedrock units occur as bands that trend predominantly east-west across the area. In reality, the units are layers stacked one on top of the other. This is shown in figure 25. The bedrock units are inclined toward the south at a dip of about 50 feet to the mile. (This gentle inclination appears relatively steep in figure 25 because the horizontal and vertical scales of the diagram are unequal.) When seen in road cuts or other small outcrops the dip of the bedrock is too small to be apparent to the eye; yet the dip produces the succession of bands we see on the map.

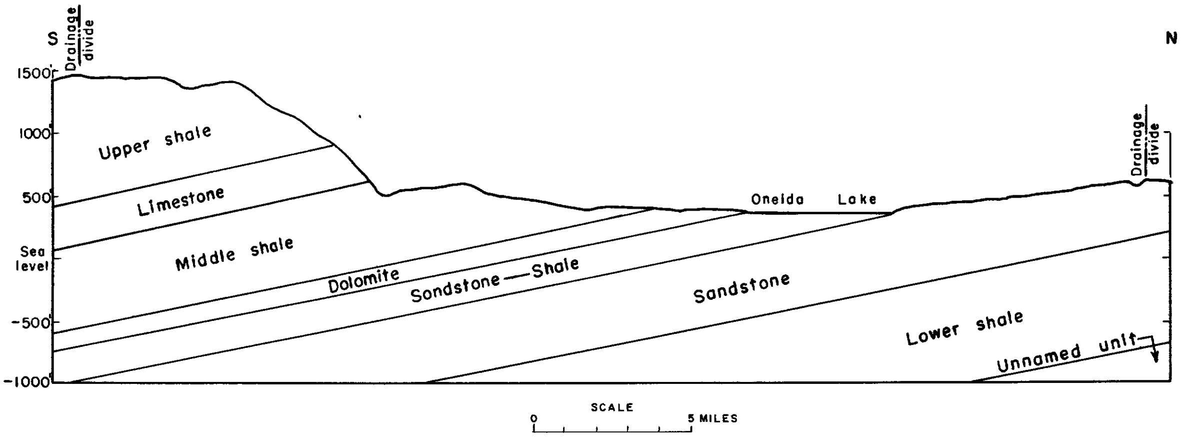


Figure 25.--The water-bearing bedrock units occur as gently dipping layers. (Generalized geologic section drawn along longitude 76°00'.)

Table 3.--Water-bearing bedrock units in the Eastern Oswego River basin

Water-bearing unit	Thickness (feet)	Yield of wells (gpm) median	Yield of wells (gpm) range low	Yield of wells (gpm) range high	Geologic rock unit	Thickness (feet)	Description
Upper shale	1,925	6	1	100	Genesee Formation	700	Black and gray shales; and some thin sandstone layers.
					Tully Limestone	25	Black limestone.
					Hamilton Group	1,200	Black shales, calcareous shales, and thin limestone layers.
Limestone	340	25	3	700	Onondaga Limestone	80	Blue-gray massive limestone.
					Manlius Limestone	130	Dark blue thin-bedded limestone.
					Rondout Limestone	35	Gray shaly dolomite.
					Cobleskill Limestone	20	Gray limestone and dolomite.
					Bertie Limestone	75	Gray dolomite, some thin shale partings, and layers of gypsum.
Middle shale	850	20	1	245	Camillus Shale	350	Gray thin-bedded shale, beds of gypsum, salt, and dolomite.
					Vernon Shale	500	Red soft shale, beds of green shale, gypsum, and dolomite.
Dolomite	150	4	1	30	Lockport Dolomite	150	Dark-gray dolomite.
Sandstone-shale	250	3	1	28	Clinton Group	250	Alternating layers of red and green shale and sandstone, and some thin beds of limestone.
Sandstone	500	10	1	125	Albion Group	400	Red fine- to coarse-grained massive sandstone.
					Oswego Sandstone	100	Gray fine-grained sandstone.
Lower shale	800	3	1	5	Lorraine Shale Utica Shale	800	Black and gray shale.

From figure 25 we can see that each bedrock unit is underlain by all the units that appear north of it on the map. Generally, the bedrock units are suitable aquifers only within their outcrop bands; the yields of the buried units are often low and the rocks usually contain highly mineralized water. However, wells located 1 mile, or less, south (west in the Tug Hill Upland) of a contact between two units may successfully draw water from both.

The nature of the water-bearing openings in the bedrock is quite different from those in unconsolidated deposits. Bedrock, like the unconsolidated deposits, is made up of individual grains or mineral particles. In bedrock, however, the spaces between the grains are almost always filled with a natural cement that holds the rocks together. Thus, bedrock had no porosity comparable to that in the unconsolidated deposits. But, because bedrock is rigidly cemented together, cracks or fractures develop in the bedrock as a result of stresses in the earth's crust. The openings along these fractures give bedrock its porosity. Figure 26 shows the nature of these openings. The total volume of openings in a bedrock unit seldom exceeds 5 percent. In contrast to this, some unconsolidated deposits have a porosity of as much as 40 percent.

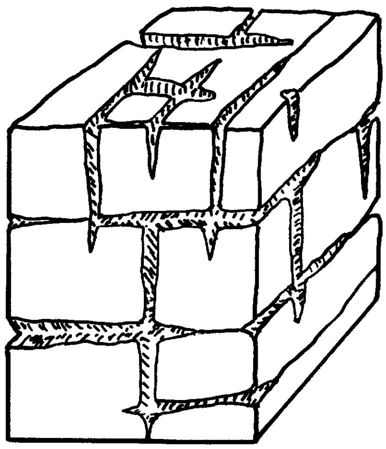


Figure 26.--The water-bearing openings in bedrock consist of a network of interconnected fractures.

The amount of water available from a bedrock unit depends on how much of its stored water can be released, in other words, on tne specific yield. We have already defined specific retention as the water that clings to a rock surface, and specific yield as the water that is free to drain. Together these two are equal to the total porosity. The specific yield of bedrock is controlled by the width of the water-bearing fractures. If the fractures are very narrow the water that wets the rock surface may completely fill the open spaces; in other words, specific retention is equal to porosity and there is no specific yield. As the width of the openings increases the amount of water that is free to drain also increases.

Little is known about the actual size of the water-bearing openings in bedrock. At outcrops the openings may be several inches across, but we notice they become smaller towards the bottom of the exposure. We have no way of knowing just how small and how widely spaced they become at depth. Based on some observations made in deep excavations near Niagara Falls, the width of the openings is less than 1/10 of an inch (Johnston, 1964). In the Eastern Oswego River basin, somewhat larger openings may be present in the limestone and middle shale units. These units contain minerals that are highly soluble in water and the natural openings doubtless have been widened by solution.

Water is obtained from bedrock almost exclusively by means of drilled wells. In the Eastern Oswego River basin, these wells are drilled by the cable-tool method -- a bit is pounded against the rock and the crushed fragments are removed by bailing. The drilled hole is cased through the unconsolidated deposits to prevent caving but is left open in the bedrock. This is shown in figure 27. Drilled wells draw water from all the water-

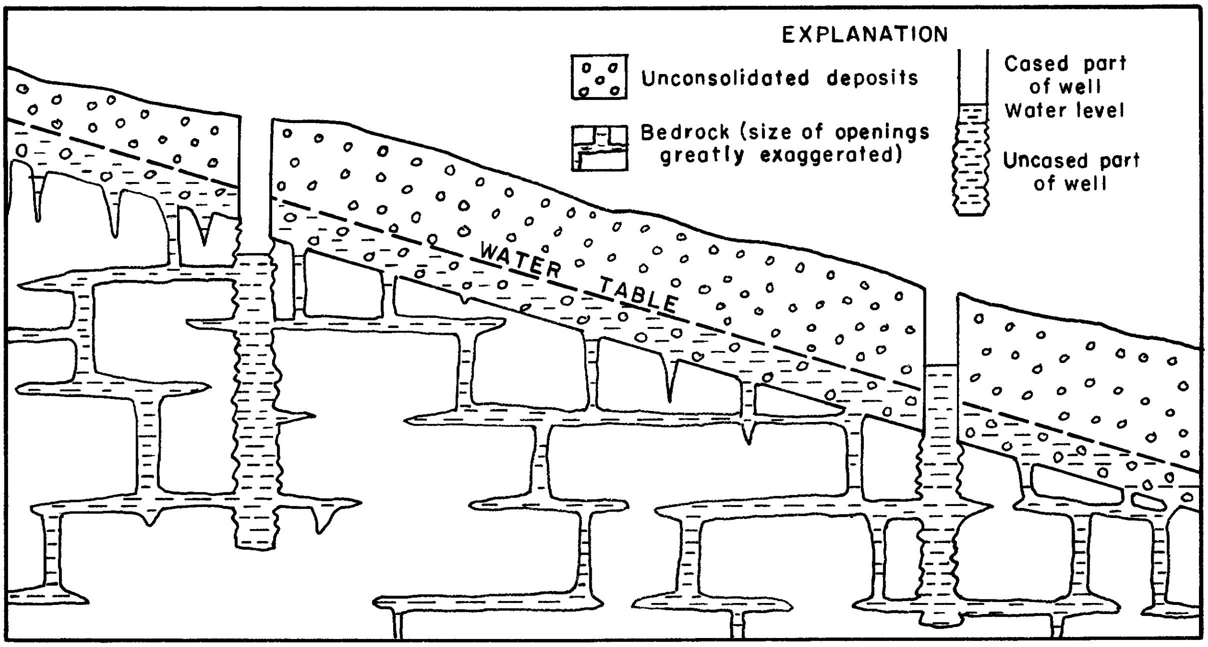


Figure 27.--Water in bedrock fractures flows into the uncased parts of drilled wells.

bearing openings they intercept. Each individual opening can store and yield only a relatively small amount of water. In order to yield usable quantities of water the openings must be interconnected to allow water from a relatively large part of the aquifer to move toward the well. Thus, the yield of a bedrock well largely depends upon the number, size, and degree of interconnection of the water-bearing openings intercepted by the drill hole.

Water in bedrock in this basin generally occurs under artesian pressure, that is, water levels in wells are almost always above the horizontal water-bearing openings that supply the water. As shown in figure 27, water levels may lie either above or below the water table in the overlying unconsolidated deposits.

We can see from figure 26 that there are two types of fractures in bedrock: vertical fractures and horizontal fractures. Obviously a small-diameter drill hole (usually 6 inches) will intersect a relatively large number of horizontal openings and few, if any, vertical openings. The vertical openings are nevertheless important because they serve as "pipelines" carrying water to the horizontal openings.

The upper surface of the bedrock is generally highly fractured. To be water bearing, this well fractured zone must first contain water; it must occur beneath the water table. Secondly, the fractures must be open; the uppermost fractures in the rock are generally filled with the overlying unconsolidated deposits. If the material filling the fractures is impermeable (clay, silt, or till), the upper zone of the rock will not yield large amounts of water. On the other hand, if the material filling the fractures is permeable (sand and gravel), or if the fractures are completely open, the upper zone will have a high yield. The zone of open fractures at the top of rock is about 10 to 20 feet thick. Wells successfully tapping this zone generally produce higher than average yields.

What happens if the upper surface of the bedrock is not well fractured or if the fractures are dry or filled with impermeable material? Although the size and interconnection of the water-bearing openings decreases with depth, adequate water supplies can usually be obtained by drilling about 50 or 100 feet into rock. In most cases, if a well is "dry" after drilling 100 feet into rock there is little to be gained by further drilling, but if some water has been obtained at that depth, increments may generally occur down to about 200 feet. On the other hand drilling more than 50 or 100 feet into rock, particularly on the Ontario-Mohawk lowland, greatly increases the chances of encountering water of poor chemical quality.

Because the limestone and middle shale units are water soluble, the nature of their openings is different than those of the other units. Water moving through the fractures dissolves the rock and carries it away in solution. The openings therefore become enlarged with time and can yield relatively large amounts of water. Because the dissolving action of ground water is generally greatest near the surface, the distribution of open fractures in the limestone and middle shale units is probably similar to that in the other bedrock units.

Data for about 270 wells tapping bedrock in the basin are summarized in table 4. Using these data -- keeping in mind however, that they are based on a random sampling of a relatively small number of wells -- we can estimate the odds of drilling a well with a particular yield, or of obtaining an adequate supply at a particular depth. For example, there is a better than even chance (51 percent) that a well in the sandstone-shale unit will yield at least 3 gpm. However, almost one out of every four wells drilled (23 percent) yields only 1 gpm or less. Therefore,

Table 4.--Summary of well yield, well depth, and water-bearing characteristics of the bedrock units in the Eastern Oswego River basin

Water-bearing unit	Yield of wells (gpm)		Percent of wells yielding the indicated amount, or less						Depth of wells (feet below land surface)		Percent of wells penetrating less than the indicated thickness of bedrock					Number of wells	Type of water-bearing openings
	Range	Median	1 gpm	3 gpm	5 gpm	20 gpm	50 gpm	100 gpm	Range	Median	10	20	50	100	200		
Upper shale	1-100	6	4	18	43	92	98	100	30-504	120	0	12	42	68	86	99	Rock fractures.
Limestone	3-700	25	0	11	20	48	81	86	28-275	114	12	18	42	52	94	19	Rock fractures enlarged by solution.
Middle shale	1-245	20	5	10	19	58	82	90	20-302	84	14	26	78	97	98	60	Rock fractures enlarged by solution.
Dolomite	1-30	4	15	39	69	85	100	100	15-132	68	12	24	61	100	100	13	Rock fractures, minor enlargement by solution.
Sandstone-shale	1-28	3	23	51	59	96	100	100	25-172	86	14	33	66	97	100	37	Rock fractures.
Sandstone	1-125	10	12	14	36	79	97	98	32-208	83	17	29	66	88	100	34	Rock fractures, some possible porosity between sand grains.
Lower shale 1/	1-5	3	12	57	100	100	100	100	34-227	94	14	24	60	100	100	8	Rock fractures.

1/ Data for the Lower shale unit is limited. If more data were available the characteristics of the Lower shale would probably resemble those of the Upper shale which it physically resembles.

minimum supplies appear to be the rule in this unit, and inadequate wells should not come as a surprise. As another example, almost four out of every five wells (78 percent) in the middle shale unit are drilled less than 50 feet into rock. Because only 1 out of every 20 wells (5 percent) yields 1 gpm or less, there is a good chance of obtaining an adequate domestic or farm supply with a shallow well.

In summary, the upper shale appears to be a rather poor aquifer but yields of 10 to 20 gpm are not uncommon and a few wells yield more. The limestone may yield abundantly; one well yields 700 gpm at a depth of 178 feet with 35 feet of drawdown. The middle shale also shows promise of yielding abundantly in places; one well 145 feet deep yields 200 gpm. The dolomite appears suitable only for very small supplies although in western New York this unit is capable of high yields (Johnston, 1964). The sandstone may yield abundantly in places; one well yields 125 gpm at a depth of 205 feet. The lower shale is a poor water-bearing formation.

THE HYDROLOGIC CYCLE

Unlike most other natural resources, such as iron, coal, or petroleum, the earth's water supply cannot be depleted permanently. It is almost impossible to destroy water -- if you boil it, it still exists as water vapor; if you pour it on the ground, it will eventually find its way back into the atmosphere or to the sea. For this reason, the total amount of water held in rivers, lakes, oceans, the atmosphere, and in the ground always remains the same. The amount held in each one of these environments, however, is always changing as water moves from one environment to another. This movement of water, without any loss in total quantity, is known as the hydrologic cycle.

Figure 28 diagrammatically shows the way the hydrologic cycle works in the Eastern Oswego River basin. Much of the precipitation that falls on the basin originates as water vapor over the Gulf of Mexico and is carried to this area by the prevailing westerly winds. Precipitation is the source of all the ground water in the basin. Figure 28 shows that not all the precipitation enters the ground; some of it is returned directly to the atmosphere and some of it becomes surface runoff. In the following paragraphs we will look at the parts of the hydrologic cycle that involve ground water.

GROUND-WATER RECHARGE

The movement of water into and out of the ground-water reservoir, as part of the hydrologic cycle, causes changes in the amount of water held in storage. Just as in any other container, whenever water is added or removed, water levels fluctuate, and we say that the water table is rising or is falling as the case may be. The addition of water to the ground-water reservoir is called recharge; the removal of water is called discharge. Figure 29 shows water-level fluctuations in three wells in the basin during the period 1961 to 1965. We can see that the overall pattern

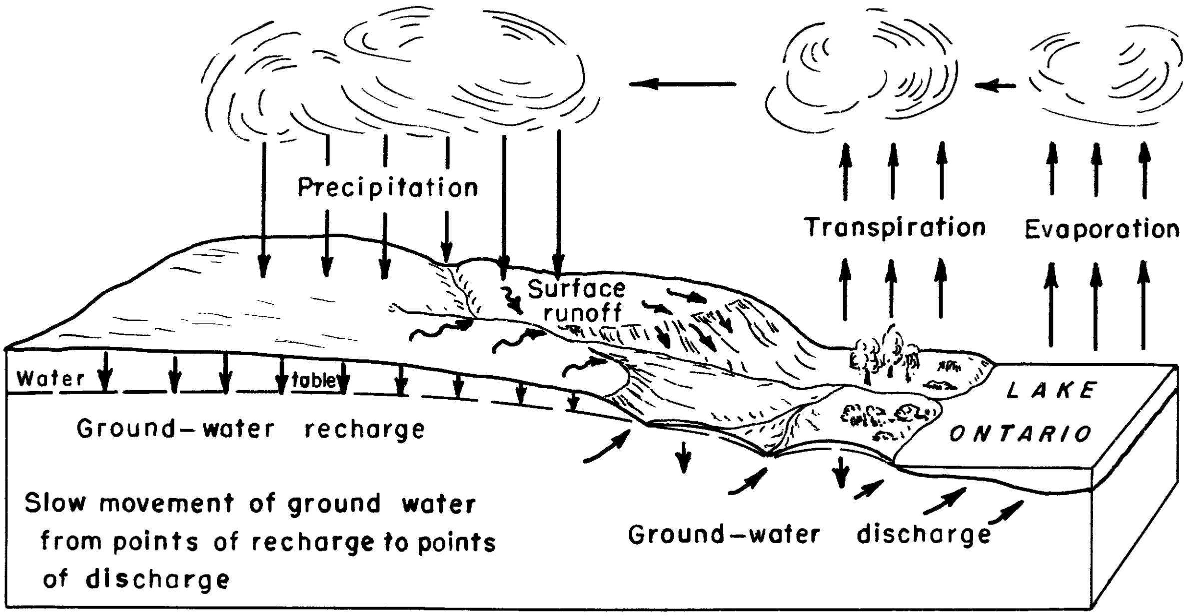


Figure 28.--Water moves from the atmosphere to the land and back again to the atmosphere.

of water-level fluctuation is repeated each year; water levels are highest during the period January through April, gradually decline through the summer and early fall, and usually begin to rise during November.

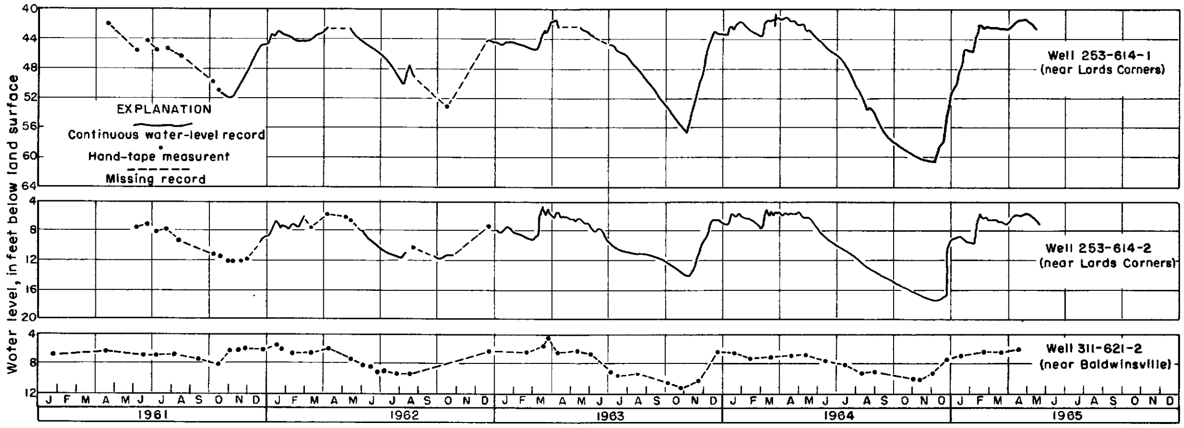


Figure 29.--Water levels are highest in the spring and lowest in the fall.

Precipitation is the source of all recharge. For this reason we would expect the trend of precipitation to be similar to that of the water levels; that is, water levels should be highest when precipitation is heaviest. The records of all the weather stations in the basin, however, show that precipitation is nearly uniform throughout the year, in other words, there are no "wet" or "dry" periods.

Conditions favoring recharge are greatly influenced by air temperatures. During the colder part of the year, air temperature may cause precipitation to occur as snow; however, recharge from such precipitation only takes place after a thaw. This is shown in figure 30 which compares

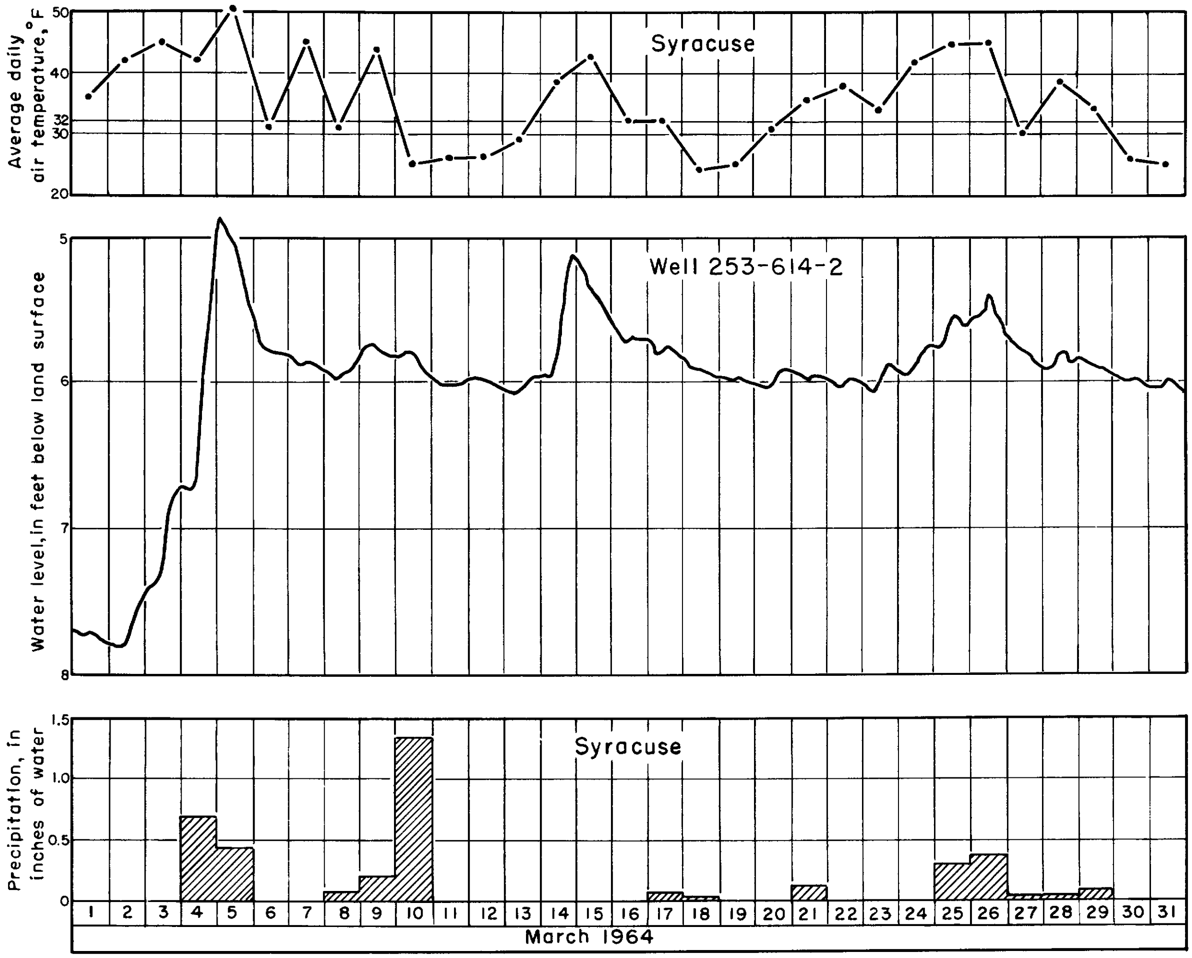


Figure 30.--Precipitation and air temperature control recharge during the winter and early spring.

water-level fluctuations in well 253-614-2 with precipitation and average daily air temperature at Syracuse. The water-level rise during March 2, 3, and 4 was caused by melting snow which recharged the ground-water reservoir. The rainfalls on March 4 and 5, and 8 and 9 resulted in almost immediate recharge. Precipitation on March 10 fell as snow, and recharge did not take place until March 14 when the average daily air temperature rose above freezing. For the remainder of the month precipitation was generally slight, but a continuous cover of snow remained on the ground. The record of water-level fluctuation for this period resembles the temperature graph; when temperature rose, recharge from melting snow occurred and water levels in the well rose.

During the warmer parts of the year, evaporation and transpiration (consumptive use by plants) combine to rob potential recharge, but because water lost to transpiration enables plants to grow, we need not feel too indignant about this robbery. Rain falling on the ground either becomes surface runoff, is evaporated, or seeps into the soil. When evaporation rates are high, the relative percentage of water that seeps into the soil is decreased. However, even before the soil water can move downward into the zone of saturation, the moisture requirements of the soil must be satisfied. During the late spring and in the summer, evaporation and transpiration create a moisture deficiency in the soil zone. Water seeping into the ground must first wet the soil before any excess water can move downward to become recharge. Evaporation and transpiration during the period May through September are so effective in drying out the soil that the moisture deficiency is generally carried over into October, and in dry years, into November or December. In the colder part of the year, after soil moisture requirements are satisfied, most of the water that seeps into the ground is able to reach the water table.

Figure 31 summarizes what happens to precipitation that falls on the basin. The width of the arrows are approximately proportional to the

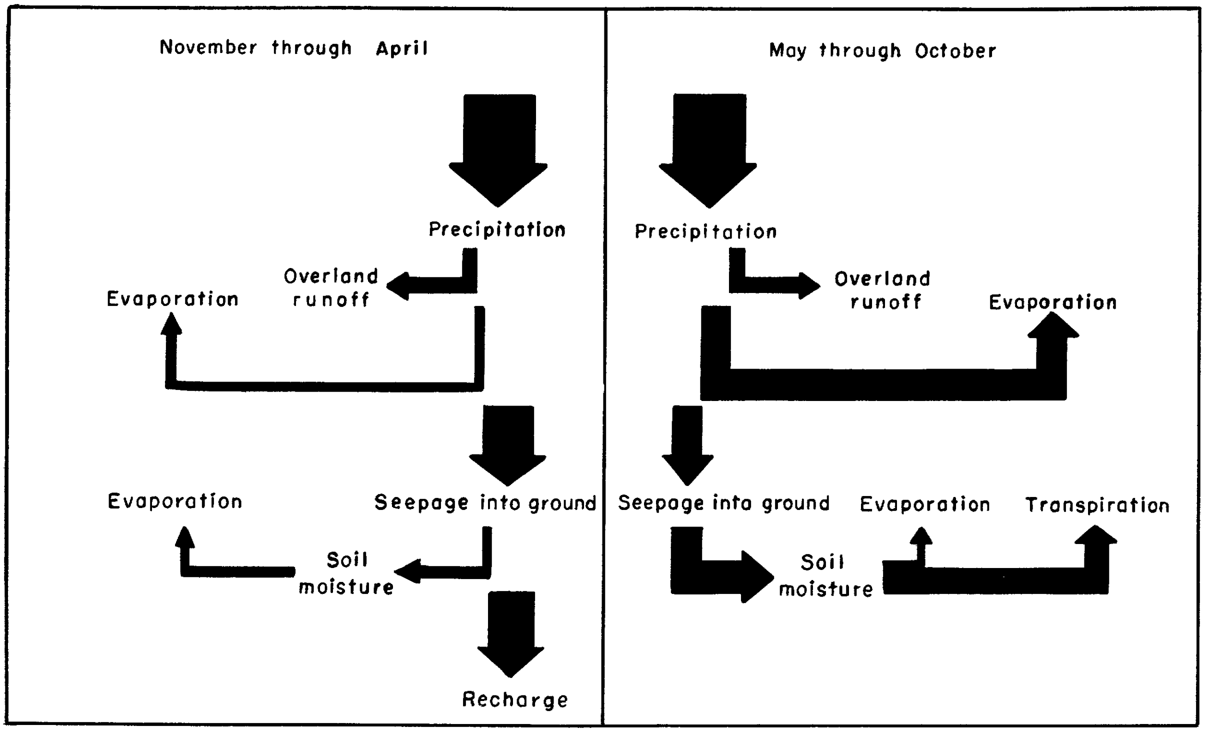


Figure 31.--Evaporation and transpiration control the availability of water for recharge.

quantities of water involved. During the recharge season (November through April), about 30 percent of the total precipitation becomes overland runoff and perhaps as much as 10 percent is evaporated from the land surface. This leaves about 60 percent of the total to seep into the ground. Another

10 percent may be used to replenish soil moisture that has been evaporated. The remaining 50 percent of the original precipitation recharges the ground-water reservoir. During the nonrecharge season (May through October), overland runoff is about 20 percent of the precipitation. Evaporation from the land surface increases as much as four times to about 40 percent. Therefore, only about 40 percent of the precipitation is able to seep into the ground. Virtually all of this water is held in the soil zone and is eventually evaporated or transpired. Thus, during the warm part of the year no ground-water recharge occurs except during occasional exceptionally wet periods when precipitation exceeds evaporation, transpiration, and soil-moisture requirements.

On a yearly basis, the distribution of precipitation is as follows: 25 percent flows directly to surface-water bodies as overland runoff; 50 percent is returned directly to the atmosphere by the combined processes of evaporation and transpiration; and 25 percent recharges the ground-water reservoir. The average annual precipitation in the basin is about 35 inches; therefore, ground-water recharge averages about 8 1/2 inches per year. This quantity may be expressed as 400,000 gallons of water per day per square mile or a total of about 1 billion gallons per day for the entire basin. To sum up why water levels rise, we might restate these figures in yet another way: on the average, almost 150 million gallons of water are added to each square mile of the ground-water reservoir during the 6 month recharge period.

GROUND-WATER MOVEMENT AND DISCHARGE

We have seen that recharge takes place at intervals during the winter and early spring. Discharge, on the other hand, takes place continuously throughout the year. When recharge is greater than discharge, water levels rise; when recharge is less than discharge, or when there is no recharge at all, water levels decline. Annual rates of recharge and discharge are approximately balanced; that is, about 150 million gallons of water are discharged from each square mile of the ground-water reservoir during a year.

Where is ground water discharged? Every time we look at the dry-weather flow of a stream we are actually seeing discharged ground water. Streams, rivers, springs, swamps, and lakes frequently are places where the land surface lies below the water table; they are the places where the ground-water reservoir overflows.

Ground water is constantly moving toward discharge areas, but movement of any kind requires a source of energy. We know that water on the earth's surface runs downhill under the influence of gravity. In a somewhat similar way, ground water moves from high areas to low areas. The water table, or top of the zone of saturation, is highest under hills or interstream areas and is lowest under valleys; that is, the water table generally has a shape similar to that of the overlying land surface. This is shown in figure 32. Thus, ground water moves toward streams, lakes, or swamps occupying the lowest areas on the water table.

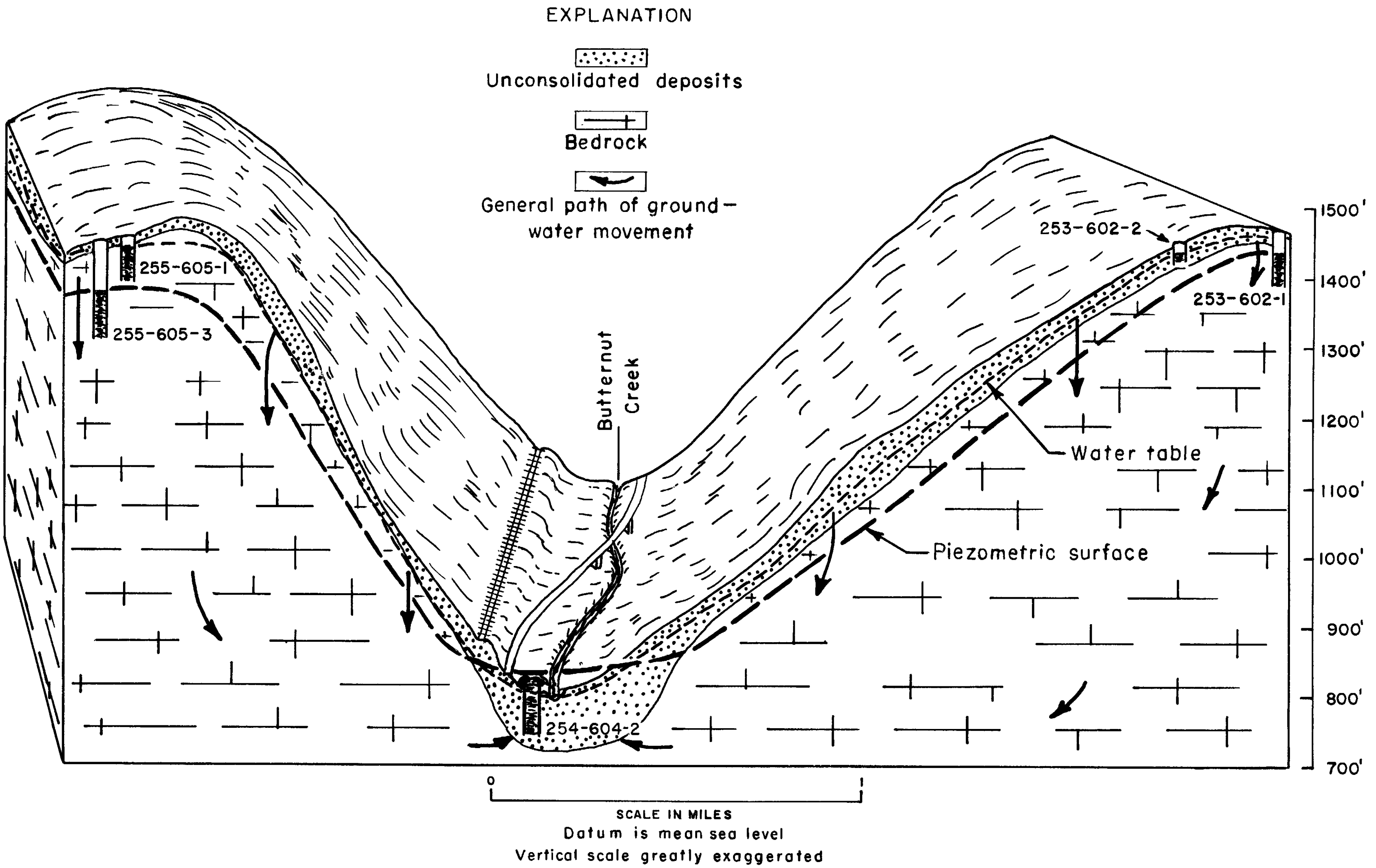


Figure 32.--The water table and piezometric surface have the same general shape as the land surface.

This is an extreme over simplification of the way ground water moves. In nature ground water sometimes seems to move "uphill". Apparent uphill movement happens when ground water occurs under artesian pressures. (See figure 18.) The confining material creating the artesian conditions is never completely waterproof; water is able to move into or out of the aquifer according to the existing pressure relationships. When the water table is higher than the piezometric surface, water moves downward to recharge the artesian aquifer. When the piezometric surface is higher than the water table, water moves upward and discharges from the artesian aquifer.

The first condition, water table higher than the piezometric surface, is illustrated by the two pairs of hilltop wells in figure 32. Ground water moves from the water-table aquifer (in the unconsolidated deposits and in the upper part of the bedrock) into the artesian aquifer (in the lower part of the bedrock). Actually, each water-bearing opening in the bedrock may have a distinct water level and, therefore, figure 32 is only diagrammatic.

The second condition, piezometric surface higher than the water table, exists in the valley of Butternut Creek (fig. 32). Ground water moves from the artesian aquifer (in the bedrock and lower part of the unconsolidated deposits) into the water-table aquifer (in the upper part of the unconsolidated deposits). Even when water appears to move uphill it is only moving in response to pressure driving it from areas of higher to areas of lower pressure.

The rate at which ground water moves toward discharge areas is controlled by: (1) the physical nature of the material it is moving through, and (2) the hydraulic gradient (the difference in water levels within the ground-water reservoir). The more permeable the material (the larger the openings and the better their interconnection), and the greater the hydraulic gradient, the faster ground water can move. In the Eastern Oswego River basin, ground water, even in the most permeable aquifers, rarely moves at a rate of more than one foot per day. It is interesting to compare this rate with that of water in stream channels. The velocity of streamflow is often more than one foot per second, more than 100,000 times faster than the rate of ground-water movement.

WATER-LEVEL FLUCTUATIONS

Water levels in the basin fluctuate as much as 25 feet per year under hilltops and generally less than 5 feet per year under lowlands. To understand why annual water-level fluctuations may be of such magnitude let's make the following assumptions:

1. The average specific yield of all the rocks in the basin is 5 percent; therefore, in each square mile 10.5 million gallons of water are stored in each foot of the saturated zone; and

2. ground-water discharge averages about 0.4 mgd per square mile (assuming average discharge is equal to the rate of recharge).

During periods when there is no recharge, water levels should therefore, decline at an average rate of 1 foot every 26 days. This gives an average decline of 7 feet during the months of May through October, which is probably close to the actual average.

The ground-water reservoir under a hilltop is recharged only by precipitation falling on the hilltop itself. Water levels under hilltops decline rather rapidly after periods of recharge because ground water is always moving toward lower areas. The water moving into lower areas is, in a sense, a source of recharge to those areas, in addition to the precipitation falling on them. Ground water moving from higher altitudes prevents the water table from declining as rapidly on hillsides as it does on hilltops. The lower down on the hill, the more the quantity of this "recharge" that is received. The maximum is received in valley areas and it is here that water-level fluctuations are at a minimum. Figure 33 diagrammatically shows the annual extremes in the positions of the water table. Piezometric surfaces undergo similar annual fluctuations although they usually maintain their relative position with respect to the water table (fig. 32).

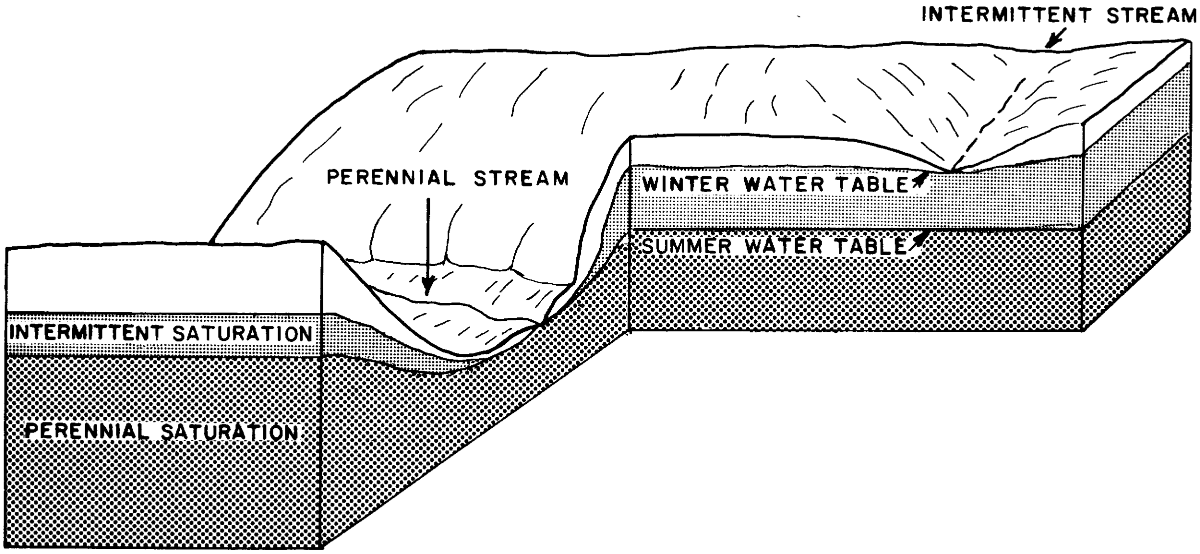


Figure 33.--Water-level fluctuations are greatest under hilltops and least under major valleys.

The seasonal variations in the position of the water level is probably the most common cause of well failure in the basin. From figure 33 we can see that if wells are not deep enough to penetrate the zone of perennial saturation, a normal seasonal decline in water level will leave the well high and dry.

In addition to changes in ground-water storage, water-level fluctuations may also be caused by tides, earthquakes, trains, and changes in barometric pressure. For example, the rapid fluctuation of the water

level in well 253-614-1 in late March, 1964, shown in figure 29, resulted from the "Good-Friday" earthquake in Alaska. Such fluctuations, however, are generally minor and are not significant as far as ground-water supplies are concerned.

Water-level fluctuations resulting from pumpage of ground water are of greater significance. When we pump a well, we are removing water from the ground-water reservoir. This decreases the amount of water in storage and causes the water level in the pumped well to fall. This decline in water level is called drawdown. Pumping not only causes drawdown in the pumping well itself but also in an area surrounding the well. This area is called the cone of depression because the water table around a pumping well resembles an inverted cone with the well at its center.

Water levels are lowered in any well located within the cone of depression. This is illustrated in figure 34 which shows a graph of the water level in well 302-609-1 in downtown Syracuse. This unused well is located about 200 feet from well 302-609-2, which supplies cooling water for an air-conditioning unit in a department store. During warm weather, well-2 is continuously pumped as long as the store is open. When the pump is turned on, between 7 and 8 a.m., the water level in well-1 is drawn down. The water level keeps declining as long as water is being removed from storage. When pumpage stops, about 5 p.m. on Tuesday, Wednesday, Thursday, and Saturday, and about 9 p.m. on Monday and Friday, the water level in well 302-609-1 begins to recover. Because the cone of depression represents a local low point on the water table, water continues to move toward it even though pumpage has stopped. This explains why water levels recover -- they are responding to the filling of the cone of depression.

Just what is the overall effect of pumpage on water levels in the basin? First keep in mind that the average pumpage of 21 mgd (table 1) is only 2 percent of the estimated average recharge of 1,000 mgd. Net withdrawal of water from the ground-water reservoir is even less than this. Almost all of the domestic pumpage and part of the public, industrial, and commercial pumpage is returned to the ground by septic tanks or other waste-disposal methods. The remainder, the net withdrawal, is probably less than 10 mgd.

Under natural conditions, virtually all ground-water discharge would appear as streamflow. However, about 10 mgd (the net withdrawal) is being taken out of the ground and artifically put into the streams as sewage. Natural ground-water discharge is therefore reduced by 10 mgd. Ground-water discharge is proportional to the pressure gradient within the aquifer; a reduction in discharge means that the slopes of the water table and piezometric surface have also been reduced. From figure 33 we can see that reduced water-table slopes are associated with a lowering of water levels. At the present rate of ground-water consumption, this lowering of water levels is confined to the vicinity of pumping wells and the overall effect of pumpage is negligible.

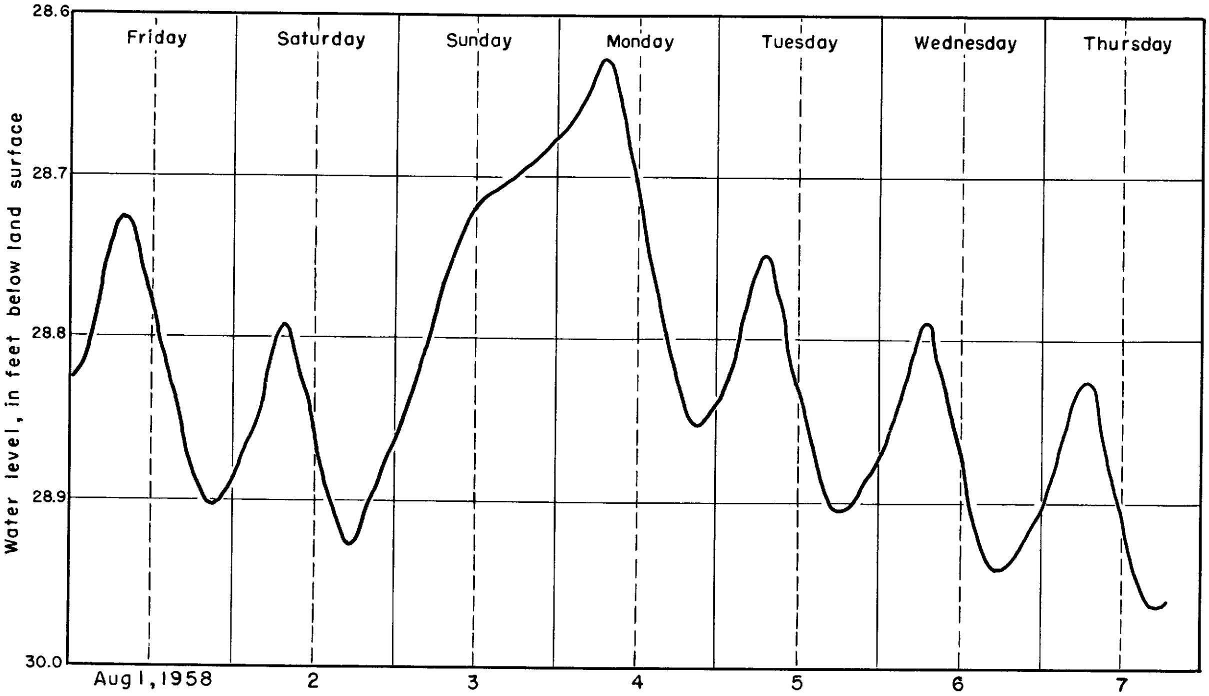


Figure 34.--Water levels in the ground-water reservoir are affected by pumping.

Because of a relatively high recharge rate and the large amount of water held in storage, the total ground-water pumpage in the basin can be increased many fold without significant lowering of the water table. This does not mean that overly large increases in pumpage would have no local or even regional effect. Wherever long term heavy withdrawal occurs ground-water levels will decline in the vicinity of the well field and may cause some shallow wells to go dry.

YIELD OF UNCONSOLIDATED AQUIFERS

Approximate yields for properly constructed wells in the unconsolidated deposits are indicated in plates 1 and 2. These data will generally be adequate for most users of this report; they will allow an individual to determine the availability of ground water for domestic, farm and small industrial and commercial supplies. Yields of individual wells, however, do not give us the full picture of water availability; for example, they do not tell us how many wells may be drilled into a particular aquifer or how much water may be pumped from an aquifer without drying it up. These are the problems that frequently confront those responsible for planning large scale public and industrial supplies. To develop a complete picture of water availability we must understand the two factors that affect both well and aquifer yields. These factors are (1) the hydraulic characteristics of the aquifer, and (2) the rates of recharge to the aquifers.

HYDRAULIC CHARACTERISTICS

The physical properties of a material determine its capacity as an aquifer. We have seen that the ability of a geologic material to store and transmit water is controlled by the degree of sorting and the size of the particles that comprise it. Furthermore, we have seen that of all the unconsolidated deposits only those composed of sand and gravel are well sorted enough and are coarse enough to be considered as aquifers. Therefore, the following discussion will be limited to sand and gravel aquifers, including gravel-free sand and those mixed deposits that contain substantial amounts of sand and gravel.

In order to make quantitative estimates of the behavior of sand and gravel aquifers, we must relate their capacity to transmit and store water to measurable hydraulic characteristics. The quantitative expressions of these characteristics are referred to as the coefficients of transmissibility and storage. The coefficient of transmissibility is defined as the rate of flow, in gallons per day, at the prevailing water temperature, that would occur through a 1-foot wide vertical section of the aquifer under a hydraulic gradient of 1 foot per foot. It is expressed as gallons per day per foot (gpd per foot). The storage coefficient is the volume of water that will drain by gravity from a vertical section of the aquifer with a base area of 1 square foot when the water level is lowered 1 foot. It is expressed as a dimensionless decimal.

Numerical values for the aquifer coefficients are determined from aquifer tests; that is, the observation of the way water levels in wells respond to pumping. Table 5 summarizes the available data on aquifer coefficients of sand and gravel deposits in the basin. The aquifer-test data were analyzed by the Theis nonequilibrium method described by Ferris and others (1962, p. 92-98).

Table 5.--Aquifer coefficients of sand and gravel deposits in the Eastern Oswego River basin

Well number	Transmissibility (gallons per day per foot)	Storage coefficient
301-600-2	34,000	0.0002
305-545-1,-3	64,000	.0004
259-559-3	263,000	.0001
302-609-1,-2	550,000	.2 e/
305-543-1	695,000	.003
259-609-1	797,000	.2 e/

e/ Estimated.

The coefficients of storage shown in table 5 reflect the manner in which water is stored and released in the aquifers. In water-table aquifers, water is stored under atmospheric pressure and is released during pumping by simple drainage. The coefficient of storage is therefore equivalent to the specific yield of the aquifer and the values are relatively high. According to Ferris and others (1962, p. 78), the storage coefficients of water-table

aquifers range from about 0.05 to 0.30. In artesian aquifers water is stored under pressure higher than atmospheric pressure. Water is released from storage as a result of a minute expansion of the water and a minor compaction of the aquifer. The values of the storage coefficients of artesian aquifers are quite low and range from about 0.00001 to 0.001 (Ferris and others, 1962, p. 76).

All the wells listed in table 5 tap deposits consisting of gravel and relatively coarse sand. These deposits are mapped as sand and gravel in plates 1 and 2; based on data in table 5 they range in transmissibility from about 30,000 to 800,000 gpd per foot. Data available for well 309-634-1, which taps a deposit consisting of fine sand, are incomplete and do not allow an analysis of nonequilibrium method. Nevertheless, the data suggest that the sand deposit has a transmissibility of about 5,000 gpd per foot. The probable range of transmissibilities for the sand aquifers shown in plates 1 and 2 is about 1,000 to 10,000 gpd per foot.

No data are available to determine the aquifer coefficients of the sand and gravel within the mixed deposits. Based on their physical properties, the gravel and relatively coarse sand that comprise much of the mixed deposits in the Appalachian Upland have a coefficient of transmissibility in the range of 10,000 to 50,000 gpd per foot. The generally finer grained sand and gravel found in the mixed deposits in the Tug Hill Upland probably have a coefficient of transmissibility ranging from near 1,000 to perhaps as much as 30,000 gpd per foot.

Transmissibility controls the shape of the cone of depression about a pumping well. When transmissibility is low, ground water moves slowly toward a pumping well. Much of the water withdrawn from the aquifer comes from storage in the immediate vicinity of the well. The immediate effect of the pumping is limited to a small part of the aquifer; however, the drawdown near the well is large. Where transmissibility is high, water moves readily toward a pumping well. The water moving toward the well replaces part of the water taken from storage. The effect of the pumping is spread out over a large part of the aquifer, but the drawdown at any point is relatively small. The storage coefficient affects the rate of spread of the cone of depression about a pumping well. When the coefficient is high, water released from storage near the well is almost equal to the pumpage and the cone of depression expands slowly. When the coefficient is low, the amount of water released from storage near the well is far less than the amount of pumpage and the cone of depression expands rapidly.

Knowledge of the coefficients of storage and transmissibility can provide quantitative as well as qualitative predictions of the response of an aquifer to ground-water withdrawals. The drawdown at any point in an aquifer, at any time, resulting from any pumping rate, can be determined according to a procedure worked out by Theis (1963a, p. 10-15). Theis (1963b, p. 113-115) has also developed a method of determining optimum well spacing that depends upon aquifer transmissibility, pumping rate, and various cost factors. Intensive ground-water development should not be undertaken without first determining the hydraulic characteristics of the aquifer. Ordinarily this requires the services of a ground-water specialist.

The coefficients of transmissibility and storage describe mathematically the way an aquifer responds to pumping. Specific capacity is a factor that describes the way a well itself responds to pumping. The specific capacity of a well is determined by dividing the pumping rate by the water-level drawdown in the well, and is expressed as gallons per minute per foot of drawdown. It is a measure of the maximum amount of water a well can pump within the limits of the available drawdown. One of the things that affects specific capacity is well construction and development. The larger the well diameter and the more effective the well screen and gravel pack, the higher the specific capacity will be. Keeping a record of the specific capacity of a well or comparing specific capacities of similarly constructed wells in a well field can point out inefficiencies such as clogged or collapsed screens and poor well development.

Specific capacity is related to the transmissibility of the aquifer; generally, the higher the specific capacity the higher the transmissibility. To a lesser extent, specific capacity is also related to storage; for any given transmissibility the higher the coefficient of storage the higher the specific capacity. In fact, if the coefficients of storage and transmissibility are known, the specific capacity for a well of any diameter can be determined. Conversely, if the specific capacity is known and the storage coefficient can be estimated, it is possible to estimate the coefficient of transmissibility. The mathematical basis and graphical procedures for these computations are presented in a paper by Theis, Brown, and Meyer (1963).

Specific capacities of wells ending in sand and gravel in the Eastern Oswego River basin range from about 2 to more than 500 gpm per foot of drawdown. The areal variation of specific capacity is shown in figure 35. These values apply to thoroughly developed screened wells.

RECHARGE

On the basis of their hydraulic characteristics, the sand and gravel aquifers, particularly the gravel-bearing deposits, are physically able to yield almost unlimited quantities of water. It is axiomatic, however, that an aquifer cannot yield water that is not there! There is, of course, a tremendous quantity of water stored in the sand and gravel aquifers. For example, about 30 billion gallons of water is stored in the surficial sand and gravel aquifer northwest of Camden (pl. 1). It would be impossible to withdraw all this storage because some water must remain in the ground to permit ground-water flow. However, if a large number of wells were drilled into the aquifer, it might be possible to withdraw as much as 20 billion gallons. If the wells were pumped at a combined rate of 60 mgd, storage within the aquifer would be depleted in about 330 days. But there is another source of water in addition to storage. This source is called "recharge" and is water that is added to the ground-water reservoir, largely as a result of the infiltration of precipitation or streamflow. The aquifer northwest of Camden has a potentially high rate of recharge and, in fact, is probably capable of yielding 60 mgd indefinitely. The total amount of recharge available to sand and gravel aquifers defines the maximum water yield of the aquifers.

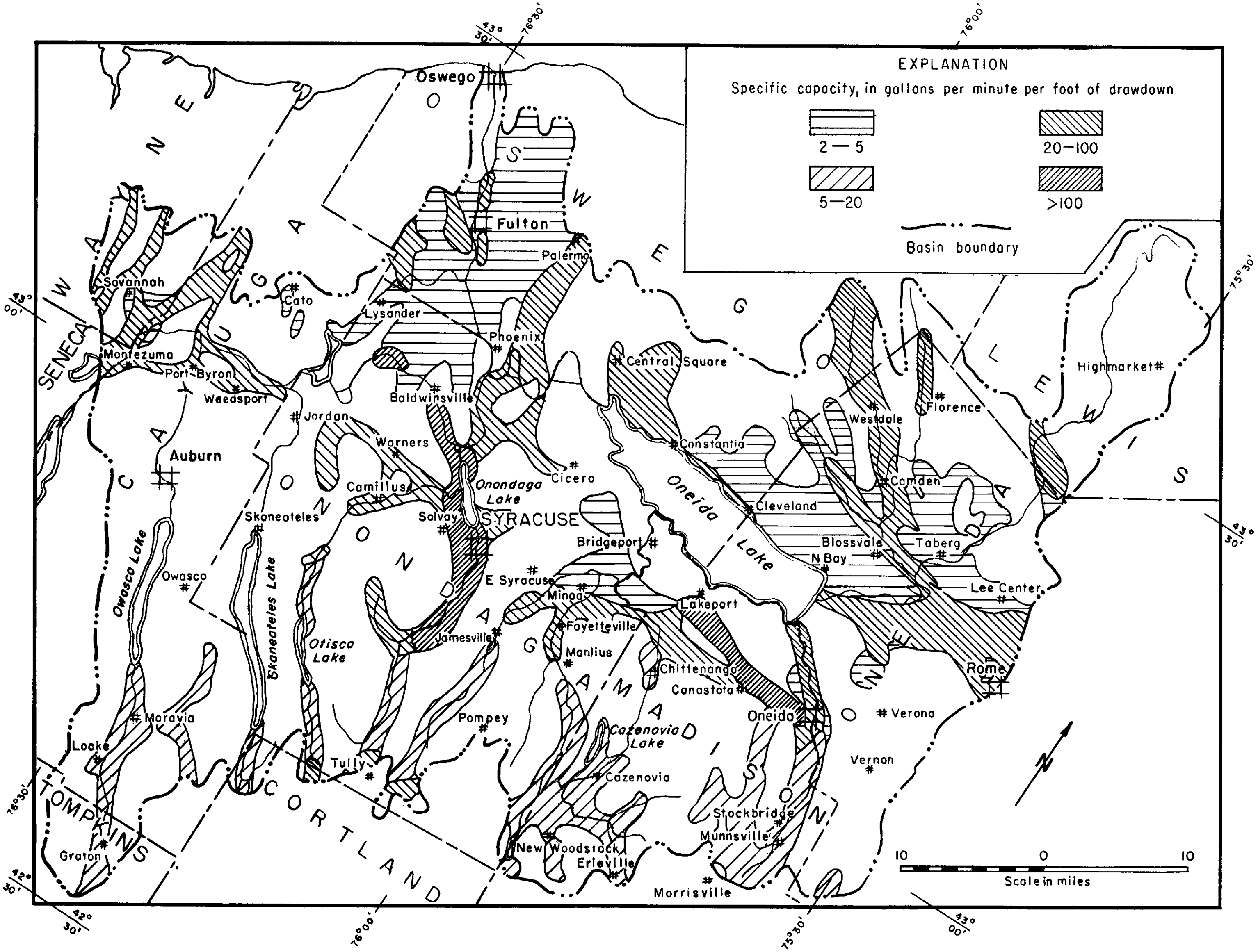


Figure 35.--Specific capacities of wells ending in sand and gravel range from about 2 to more than 500 gpm per foot of drawdown.

Plate 5 shows the yield, in million gallons per day, of the gravel-bearing aquifers in the basin. As we have already seen in plates 1 and 2, the aquifers may be classified into three types on the basis of their manner of recharge. These aquifer types and the methods used to determine their yields are as follows:

1. Sand and gravel at land surface.--It is assumed that 25 percent of the precipitation falling on sand and gravel is able to infiltrate into the ground. This amount of infiltration is equivalent to a recharge rate of about 0.6 mgd per square mile of aquifer surface in the Tug Hill Upland and about 0.5 mgd per square mile in the remainder of the area. Many of the surficial sand and gravel aquifers (particularly in the Appalachian and Tug Hill Uplands) are located in valleys and thus receive additional recharge in the form of storm runoff from adjacent hills. Recharge to the surficial aquifers from storm runoff is also assumed to be about 25 percent of the precipitation falling on the areas directly tributary to the aquifers.

2. Sand and gravel at land surface that is favorably situated with respect to stream infiltration.--These aquifers receive natural recharge in the manner outlined above. As we have already seen in figure 17, they may also receive additional recharge in the form of induced stream infiltration. The amount of water that can be obtained from stream infiltration is largely controlled by the coefficient of permeability of the streambed material. (The coefficient of permeability is equal to the coefficient of transmissibility divided by aquifer thickness in feet, and is expressed as gallons per day per square foot of aquifer.) The permeability of the gravel-bearing aquifers in the basin ranges from about 500 to as much as 2,000 gpd per square foot. Stream bottoms are likely to be covered by silt and very fine sand which reduces their permeability to about 50 gpd per square foot. According to Darcy's Law (Ferris and others, 1962, p. 73), the amount of water that can drain by gravity through a given material is equal to the product of the coefficient of permeability of the material and its cross-sectional area. Gravity drainage is possible whenever water levels in the aquifer are lowered below the bottom of the streambed material. At such times the rate of infiltration per thousand feet of channel length is equal to 50,000 gpd per foot of channel width. For example, the infiltration from a 1 mile length of a stream with a channel 10 foot wide is about 2.6 mgd. Theoretical yields for all sand and gravel aquifers where infiltration supplies are thought likely were computed by Darcy's Law. These values were then compared to: (a) the available streamflow at each site; (b) the ability of the available storage within the aquifer to make up for streamflow deficiencies, if any; and (c) the ability of the aquifer to transmit water from the stream to the wells (again using Darcy's Law). Estimates of the maximum perennial yields of the infiltration supplies are shown in plate 5.

3. Sand and gravel buried beneath less permeable deposits.--It is obvious that buried aquifers cannot receive direct recharge from precipitation, overland runoff, or induced infiltration. These aquifers must be recharged by ground water moving from adjacent unconsolidated deposits or bedrock units. Plates 1 and 2 show that, at least in a two-dimensional plan view, almost all the buried sand and gravel aquifers are adjacent to surficial sand and gravel or mixed deposits. Wherever these deposits are in actual physical contact, recharge to the buried aquifer will be relatively large. In such cases, however, the yield of both the surficial and buried aquifers must be considered as a unit; any ground water withdrawn from the recharging surface aquifer will reduce the available yield of the buried aquifer. The total water available to surficial-buried aquifer systems is equal to recharge to the surface aquifer (computed by the method outlined in paragraph number 1 above) plus a small amount of recharge to the buried aquifer in the form of ground-water movement from adjacent relatively impermeable material. This latter recharge value is assumed to be 50,000 gpd per square mile of area directly tributary to the buried aquifer. Buried aquifers that are in physical contact only with bedrock and impermeable unconsolidated deposits are recharged by ground-water movement that is assumed to be at a rate of 50,000 gpd per square mile of tributary area. These relatively low yielding aquifers are generally found underlying the middle reaches of the Appalachian Upland valleys and throughout much of the Ontario-Mohawk Lowland.

It must be stressed that the yields shown in plate 5 are, at best, based on incomplete data. Test drilling, aquifer testing, and other specialized studies are needed to define more fully the hydraulic characteristics, geometry, and hydrology of the aquifers. In particular, additional data are needed at each of the areas that are believed to be favorably located with respect to stream infiltration; testing is needed to verify the hydraulic connection between the aquifer and the streams and to evaluate the permeability of the streambed materials.

Obviously the development of infiltration supplies will modify the flow characteristics of the streams; in fact, many of the streams may, at times, become completely dry. Less obvious, but nevertheless true, is the fact that any withdrawal of ground water results in a decrease of natural streamflow. Large scale development of ground water must therefore be carried out with an awareness of the possible effects on the total water picture. For example, depletion of streamflow, particularly during times of low flow, reduces the ability of a stream to dilute sewage.

Water quality, which will be discussed in more detail in a later section, must be briefly mentioned here with respect to large ground-water supplies from sand and gravel aquifers. Induced infiltration supplies in the valleys of Onondaga Creek and Ninemile Creek near Amboy will doubtless yield salty ground water unusable as a public supply. The buried aquifers in the Ontario-Mohawk Lowland may also yield salt water under conditions of moderate to high pumpage. Salty ground water can, of course, be used for some industrial uses but makes a poor domestic supply and is ruinous for some industrial purposes.

YIELD OF BEDROCK AQUIFERS

The data on yields of wells in bedrock, summarized in table 4, indicate that large ground-water supplies are available only from the limestone and middle shale units. Even though the hydraulic characteristics of these units may be favorable for high yields, such yields are possible only when the bedrock receives adequate recharge. For the most part the limestone and middle shale units are recharged by ground-water movement through overlying till or clay and silt. Recharge through these nearly impermeable deposits probably ranges from 0.05 to 0.2 mgd per square mile.

Higher recharge rates, and hence potentially higher yields, can occur where the units are overlain by permeable unconsolidated deposits or where the cover of unconsolidated deposits is thin or missing and the site is crossed by a stream. Bedrock units overlain by permeable unconsolidated deposits are generally not developed as sources of large supply; it is easier to develop the unconsolidated deposits directly because the performance of sand and gravel aquifers can be predicted with far more accuracy than that of bedrock units. Wherever outcrops of the limestone or middle shale units are crossed by streams, conditions are favorable for streamflow infiltration. Only one such area, along Skaneateles Creek from about Skaneatales Falls to Hartlot, has been developed. A total of about 2 mgd are pumped from several wells tapping the limestone and middle shale units along a 1.5 mile reach of the creek, which has a drainage area of only 2 square miles. It is likely that even more water can be pumped from this area and that similar areas exist in the valleys of Ninemile Creek between Marcellus and Marcellus Falls, Butternut Creek north of Jamesville, Limestone Creek south of Manlius, Chittenango Creek midway between Chittenango and Cazenovia, and Oneida Creek southwest of Munnsville.

SUMMARY OF WATER AVAILABILITY

We have seen that virtually everywhere in the Eastern Oswego River basin the user of ground water has a choice of two sources of water: (1) the unconsolidated deposits, and (2) the bedrock. Also, there may be several types of unconsolidated deposits under or adjacent to a potential well site; less frequently, there may be two bedrock units present near a site. Therefore, the ground-water user must decide in advance on which source of water is most promising. Often he must also decide on the type of well that will be most satisfactory. These decisions should be based on three factors: (1) the quantity of water needed; (2) the quality of water needed; and (3) the cost of the water system.

The quantity of water needed for domestic and farm supplies can be estimated from table 2. Generally, 1 gpm may be considered a minimum requirement for a domestic supply and perhaps about 3 gpm for a farm supply. Of the unconsolidated deposits, saturated sand and gravel will always yield enough water for domestic and farm supplies; till, and clay and silt may, at best, yield enough water for marginal supplies. The

bedrock units generally provide a greater and more reliable supply than does till, or clay and silt. Wells in the limestone and middle shale units have excellent chances of obtaining at least minimum domestic and farm supplies. Chances of obtaining minimum supplies are good for the upper shale and sandstone units, and reasonable for the dolomite, sandstone-shale, and lower shale units.

There are differences in construction costs between the various types of wells. At any particular site it is generally less expensive to obtain water from unconsolidated deposits than it is from bedrock. Driven wells are least expensive and drilled wells are most expensive; dug wells are intermediate in cost. However, there may be little choice as to the type of well to use. Drilled wells are generally required to obtain water from bedrock and from buried unconsolidated aquifers. Dug wells are the only method of obtaining water from till, and clay and silt deposits. Sand and gravel occurring at land surface may be tapped by driven, dug, or drilled wells. Generally, driven and dug wells are somewhat better suited to gravel-free aquifers than are drilled wells. On the other hand, drilled and driven wells offer more protection against contamination than do dug wells.

Large amounts of ground water are available for industrial or public supplies from several sand and gravel aquifers and, in some places, from the limestone and middle shale units. Yields are greatest wherever the aquifers can be recharged by surface water. Large supplies from sand and gravel are obtained by means of screened drilled wells or, where the aquifers are shallow, by means of large-diameter dug wells. The bedrock units are tapped by uncased drilled wells.

What about the quality of the water? No decision concerning a ground-water supply can be made before first determining the expected water quality of the different sources. So far we have not really looked into this important aspect of ground water. We did, however, note in figure 4 that areas of poor water quality are widespread. What causes this natural poor quality? Is it limited to either the unconsolidated deposits or the bedrock? What effect does it have on use? Can the quality be improved by treatment? These questions are discussed in the following sections.

QUALITY OF GROUND WATER

There are slightly more than 100 chemical elements known to man. Of these, about 40 occur in ground water with some regularity. Generally, however, we are only interested in a small number of chemical elements and physical characteristics that most affect the usability of water. In the Eastern Oswego River basin, we will look at the total dissolved-solids content of the water, its hardness, temperature, and content of iron, manganese, fluoride, nitrate and hydrogen sulfide. We will also look closely at the salt (sodium chloride) content of the water. Table 6 lists chemical analyses of water from 84 wells and springs in the basin. These analyses form the basis for much of the following discussion.

DISSOLVED SOLIDS

Water in its purest state consists only of hydrogen and oxygen atoms linked in the familiar H_2O molecule. But water is also the closest thing to a universal solvent known to man. Given enough time, water will dissolve almost anything, and therefore pure water is never found in nature. Even rain water contains small amounts of dissolved chemicals. When rain water falls on the land surface and flows toward streams or seeps into the ground, it comes into contact with mineral matter, much of which is highly soluble. Ground water, by the very nature of its movement through minute openings in the rocks and soils, has the opportunity to dissolve relatively large quantities of minerals.

Small to moderate amounts of dissolved minerals give ground water its distinctive flavor or character. Try drinking distilled water and you will quickly realize just how flat-tasting water would be if it were not for dissolved minerals. On the other hand, many of the minerals dissolved in ground water may cause it to be hard, and some impart an unpleasant taste, odor, or color. By evaporating a known volume of water and carefully weighing the residue, we can determine the concentration of dissolved solids in a water sample. Of course, this does not tell us what minerals are present in the water but it is, nevertheless, an indication of the total mineralization of the water.

The concentration of dissolved solids in water is commonly reported as ppm (parts per million). For example, water with a dissolved-solids concentration of 100 ppm contains 100 pounds of mineral matter in each million pounds (120,000 gallons) of water. The U.S. Public Health Service (1962, p. 34) recommends that drinking water should not contain more than 500 ppm of dissolved solids. The samples of drinking water analyzed in table 6 have a range of 80 to 3,040 ppm of dissolved solids. That means that a 40-gallon tank of ground water from the basin could contain less than 1 ounce or as much as 1 pound of dissolved mineral matter. A 40-gallon tank of the most highly mineralized water found in the basin (260,000 ppm of dissolved solids) contains about 90 pounds of mineral matter; in fact, this type of water is used to manufacture commercial salt.

Table 6.--Chemical analyses of ground water from selected wells and springs in the Eastern Oswego River basin

Well number: See "Well-Numbering System" in text for explanation.

Water-bearing material: U Shale - upper shale unit
M Shale - middle shale unit
Sand-Sh - sandstone-shale unit
L Shale - lower shale unit
S & G - sand and gravel

Depth of well: All depths below land surface
r - reported
All others measured

Remarks: NYSDH - analysis by New York State Department of Health
USGS - analysis by U.S. Geological Survey
ABS - alkyl benzene sulfonate (synthetic detergents)
Al - aluminum
PO_4 - phosphate

Well or spring number	Water-bearing material	Depth of well (feet)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness (as $CaCO_3$) Calcium, magnesium	Hardness (as $CaCO_3$) Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
236-619-1	Till	15	1/16/64	--	0.04	--	--	--	--		150	--	4.0	--	3.5	--	136	13	--	7.7	4	NYSDH
249-608-1	--	r1,403	11/12/64	4.6	.21	--	1,910	67	99,300	231	117	28	155,000	1.0	--	260,000	5,040	4,950	189,000	6.7	1	USGS; density 1.198 g/ml.
249-611-1sp	Till	--	11/ 4/64	7.1	.03	0.00	60	7.0	3.4	.9	210	24	1.9	.2	4.2	199	179	6	369	7.9	1	USGS
251-545-1	U Shale	18	1/ 3/62	--	.12	--	--	--	--	--	199	--	10	--	2.0	--	210	47	--	7.0	0	NYSDH
251-551-1	S & G	6	1/17/62	--	.16	--	--	--	--	--	167	--	8.8	--	.1	--	160	23	--	7.8	0	NYSDH
251-620-1	U Shale	r105	11/ 3/64	7.3	.12	.03	4.2	.0	117	.7	304	3.0	8.6	.8	.0	297	10	0	476	7.9	2	USGS
252-554-2	do.	r102	11/ 2/64	7.0	.06	.08	102	15	1,330	3.4	286	36	2,150	.05	5.0	3,880	316	82	6,910	7.7	--	USGS
253-606-3	do.	r130	3/ 2/64	--	.08	--	--	--	--	--	311	--	62	--	1.1	--	330	75	--	7.3	2	NYSDH
253-609-1sp	do.	--	11/12/64	9.4	.12	.02	415	60	4,180	54	175	1,310	6,690	1.3	.0	13,200	1,280	1,140	20,100	6.9	1	USGS; density 1.008 g/ml.
254-619-1	S & G	r71	11/ 4/64	--	1.6	--	--	--	--	--	--	36	1.5	--	--	243	213	0	450	8.0	--	USGS
255-551-1	do.	r78	6/13/61	--	.28	.02	--	--	--	--	293	--	8.4	--	.1	--	300	60	--	7.4	0	NYSDH
255-612-4	do.	6	6/30/55	--	.03	--	--	--	--	--	311	--	3.0	--	1.3	--	320	65	--	6.9	0	NYSDH
258-535-1	do.	r163	12/15/59	--	.36	--	--	--	--	--	184	--	28	--	.3	--	1,320	1,169	--	7.0	15	NYSDH
-2	do.	r67	12/15/59	--	.08	--	--	--	--	--	240	--	11	--	.3	--	500	303	--	7.3	20	NYSDH
258-557-1	Sand	2	10/23/63	--	.02	--	--	--	--	--	260	--	2.6	--	3.8	--	260	47	--	7.7	3	NYSDH
259-559-3	S & G	30	6/26/63	--	.50	--	--	--	--	--	290	--	19	--	6.6	--	410	172	--	7.4	0	NYSDH; ABS 0.06.
259-604-1	Limestone	5	9/12/62	--	.02	--	--	--	--	--	262	--	15	--	5.3	--	490	262	--	7.5	0	NYSDH
259-605-1	do.	28	10/31/61	--	.02	--	--	--	--	--	276	--	12	--	5.3	--	360	134	--	7.5	0	NYSDH
259-609-1	S & G	r37	8/30/56	--	.25	<.01	--	--	--	--	242	--	7.0	--	.7	--	430	232	--	7.5	0	NYSDH
300-558-1sp	Limestone	--	5/31/55	6.2	.11	--	119	10	11		194	182	5.0	.1	7.4	531	338	179	677	7.9	1	USGS
			10/23/63	--	.02	--	--	--	--	--	223	--	8.6	--	6.2	--	680	497	--	7.6	0	NYSDH
300-559-1	do.	6	8/14/62	--	.90	<.01	--	--	--	--	237	--	3.0	--	6.6	--	540	346	--	7.5	0	NYSDH
300-608-1	S & G	r35	9/24/54	--	--	--	--	--	--	--	175	--	20	--	--	--	995	852	1,410	7.5	2	USGS
			6/18/57	--	.02	--	--	--	20		290	649	25	--	--	--	905	668	1,520	--	--	USGS
-2	do.	r31	3/17/54	28	--	--	--	--	--	--	305	223	712	--	1.6	--	650	400	3,090	7.5	--	USGS
			6/18/57	--	.01	--	--	--	236		386	184	334	--	--	--	465	149	1,950	7.7	--	USGS

Table 6.--Chemical analyses of ground water from selected wells and springs in the Eastern Oswego River basin (Continued)

Well or spring number	Water-bearing material	Depth of well (feet)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness (as $CaCO_3$) Calcium, magnesium	Hardness (as $CaCO_3$) Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
301-538-1	Limestone	r200	7/24/61	5.9	0.05	0.0	95	20	6.0		333	45	5.7	0.2	4.5	372	319	46	606	7.3	2	USGS; sample may have been chlorinated.
			8/ 2/62	5.2	.03	.01	99	20	8.5		345	44	6.2	.2	13	385	330	47	619	7.2	2	USGS; sample taken after chlorination.
301-600-2	S & G	r70	8/14/62	--	.02	--	--	--	--	--	233	--	27	--	5.8	--	720	529	--	7.3	0	NYSDH
			11/12/64	5.2	.07	.0	171	18	12	1.9	224	345	26	.4	5.4	762	501	317	1,020	7.6	2	USGS
-3	do.	6	10/22/63	--	.04	<.01	--	--	--	--	198	--	36	--	5.8	--	600	438	--	7.4	3	NYSDH
302-607-1	M Shale	r170	3/23/54	18	--	--	--	--	--	--	42	3,510	21,200	--	--	--	5,050	5,020	51,400	--	--	USGS
302-609-3	S & G	56	9/24/54	--	--	--	--	--	--	--	260	696	2,090	--	--	--	1,310	1,100	7,600	7.4	15	USGS
-4	do.	r132	3/18/54	22	--	--	--	--	--	--	115	3,360	42,500	--	--	--	4,420	4,330	82,500	7.7	--	USGS
			6/17/57	--	.8	--	--	--	25,800		117	3,160	40,100	--	--	--	3,920	3,830	82,600	6.9	--	USGS
302-624-2	do.	r35	11/ 2/64	8.5	.59	.04	490	12	4.3	1.8	234	1,160	5.4	.09	.0	2,100	1,270	1,080	2,120	7.5	1	USGS
302-627-2	M Shale	r240	7/28/65	7.3	.0	.0	519	188	21	4.7	220	1,790	3.6	2.0	.0	3,040	2,070	1,890	2,930	7.6	1	USGS; raw water.
302-629-1	Till	5	1/ 2/59	--	<.03	--	--	--	--	--	309	--	4.4	--	8.0	--	600	347	--	7.5	0	NYSDH
302-633-2	S & G	r13	9/ 5/56	--	.2	--	--	--	--	--	262	--	3.0	--	3.5	--	300	85	--	7.3	0	NYSDH
-3	M Shale	r145	5/ 7/55	--	1.7	--	--	--	--	--	258	--	34	--	.1	--	1,320	1,109	--	7.1	0	NYSDH
303-552-1	S & G	r64	10/ 5/55	--	.25	--	--	--	--	--	255	--	9.0	--	1.8	--	420	211	--	7.3	0	NYSDH
303-609-1	M Shale	r240	4/13/53	7.0	.03	.07	368	78	10	4.4	370	840	64	.2	7.6	1,560	1,240	936	2,090	7.0	2	USGS
			3/19/54	20	--	--	--	--	--	--	263	1,030	310	--	13	--	1,270	1,050	2,890	7.4	--	USGS
303-613-2	do.	18	2/15/56	--	.03	<.01	--	--	--	--	287	508	64	--	5.3	--	740	505	--	7.3	5	NYSDH
304-650-1	Till	17	9/25/48	--	1.2	.02	--	--	--	--	296	69	4.4	--	--	--	280	37	--	7.5	--	NYSDH
305-543-1	S & G	113	2/19/64	7.1	.25	.00	78	68	0.0		338	109	2.5	0.0	--	510	400	123	610	7.5	3	Analysed by James H. Haberer, Utica, N.Y.; PO_4 0.44; Al 0.08.
305-545-1	do.	r70	1/29/63	--	1.7	--	--	--	--	--	292	--	146	--	.1	--	580	341	--	7.3	3	NYSDH
-2	do.	r70	1/29/63	--	1.3	--	--	--	--	--	261	--	220	--	.1	--	440	226	--	7.5	2	NYSDH
-3	do.	65	5/15/50	--	1.3	.03	--	--	--	--	284	129	68	--	.4	579	360	137	--	7.5	5	NYSDH
305-605-1	M Shale	r57	3/15/54	16	--	--	--	--	--	--	224	1,340	94	--	.2	--	1,740	1,560	2,530	7.0	--	USGS
			6/17/57	--	.02	--	--	--	64		218	1,410	108	--	--	--	1,660	1,480	2,860	7.4	--	USGS
305-607-1	do.	r300	3/19/54	14	--	--	--	--	--	--	295	530	36	--	1.4	--	760	518	1,420	7.3	--	USGS
			5/ 3/56	5.5	3.5	.13	227	29	12	2.7	288	439	24	.0	.9	--	686	450	1,210	7.6	--	USGS
305-645-1	S & G	17	6/30/64	--	.02	--	--	--	--	--	182	--	8.0	--	13	--	330	181	--	7.6	0	NYSDH
307-602-1	M Shale	18	10/ 8/62	6.1	.26	.06	591	46	9.7		298	1,360	17	.1	.0	2,370	1,660	1,420	2,390	7.4	1	USGS
307-615-3	Sand	7	7/22/54	--	.10	--	--	--	--	--	245	--	14	--	15	--	370	169	--	7.3	0	NYSDH
308-534-1	S & G	r23	3/ 3/58	--	<.03	--	--	--	--	--	199	--	4.6	--	22	--	230	67	--	7.7	0	NYSDH

Table 6.--Chemical analyses of ground water from selected wells and springs in the Eastern Oswego River basin (Continued)

Well or spring number	Water-bearing material	Depth of well (feet)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness (as $CaCO_3$) Calcium, magnesium	Hardness (as $CaCO_3$) Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
308-536-1	Sand-Sh	88	11/ 4/64	9.5	0.43	0.02	22	9.9	50	4.7	228	0.2	18	0.4	1.3	219	96	0	398	7.6	5	USGS
-2	do.	r72	1/16/52	9.2	.03	--	681	245	5,330		145	.9	10,000	.7	79	16,200	2,710	2,590	24,300	7.3	6	USGS; specific gravity 1.013.
308-620-2	S & G	r19	6/ 1/55	8.8	.22	--	68	10	25		224	45	16	.0	14	318	211	27	531	7.6	1	USGS
			1/16/59	--	.32	--	--	--	--	--	294	--	20	--	18	--	320	79	--	7.4	10	NYSDH
309-536-1	Sand	28	11/ 4/64	--	.41	--	--	--	--	--	--	16	54	--	--	427	234	0	785	7.8	--	USGS
309-616-2	M Shale	r74	9/10/62	--	.6	--	--	--	--	--	232	--	86	--	.1	--	1,480	1,290	--	7.4	0	NYSDH
309-620-1	S & G	24	12/28/57	--	<.3	--	--	--	--	--	176	--	71	--	.7	--	240	96	--	7.9	0	NYSDH
309-624-1	do.	91	3/12/63	--	.26	--	--	--	--	--	239	--	36	--	4.0	--	240	44	--	7.7	0	NYSDH
309-631-1	M Shale	r75	11/13/64	6.6	3.4	.04	701	7.5	576	118	128	1,320	1,230	.8	.0	4,320	1,780	1,680	5,830	7.6	1	USGS
309-634-1	Sand	r52	1/21/63	--	.96	--	--	--	--	--	312	26	26	<.05	.1	--	380	134	--	7.4	3	NYSDH
309-651-1	Dolomite	r74	11/17/47	--	1.3	.01	--	--	--	--	245	24	2.4	--	--	--	300	99	--	7.6	--	NYSDH
310-608-2	do.	r60	11/ 4/64	6.8	.19	.01	35	7.5	42	36	156	70	59	.07	.5	344	118	0	600	7.8	4	USGS
310-635-2	M Shale	r54	8/ 7/61	--	.8	--	--	--	--	--	267	--	46	.75	.4	--	490	271	--	7.3	0	NYSDH
310-643-1	Dolomite	r154	9/26/48	--	.45	.02	--	--	--	--	195	72	2.2	--	--	--	156	0	--	7.7	--	NYSDH
313-544-1	S & G	5	4/24/64	--	.04	--	--	--	--	--	60	--	5.0	--	4.1	--	68	19	--	6.9	2	NYSDH
314-529-1	Sand	r22	7/ 9/56	16	.68	.25	44	8.9	22		180	3.7	30	.0	.2	216	147	0	371	7.8	8	USGS
			8/ 7/57	13	2.4	.24	41	11	14		178	.7	23	.0	.0	201	149	3	344	7.0	15	USGS
314-614-1	S & G	25	5/ 9/62	--	.6	--	--	--	--	--	189	--	10	.2	.3	--	142	0	--	7.5	35	NYSDH
-2	do.	45	5/ 9/62	--	.3	--	--	--	--	--	249	--	4.8	.2	.3	--	164	0	--	7.5	0	NYSDH
315-541-1	S & G	r78	2/12/63	--	.06	--	--	--	--	--	117	--	2.2	--	.1	--	96	0	--	8.2	3	NYSDH
315-552-1sp	do.	--	5/15/62	--	.14	<.01	--	--	--	--	48	--	.2	.1	.4	--	52	13	--	7.6	12	NYSDH
315-621-1	do.	r10	5/ 1/56	--	.03	--	--	--	--	--	128	--	2.2	--	3.1	--	164	59	--	7.9	5	NYSDH
317-608-1	do.	r21	4/11/63	--	.06	--	--	--	--	--	170	--	102	.05	14	--	216	77	--	--	0	NYSDH
317-623-2	do.	r38	4/11/61	--	.24	--	--	--	--	--	201	--	235	.05	2.2	--	390	225	--	7.2	10	NYSDH
-3	do.	r38	4/30/63	--	.02	--	--	--	--	--	138	--	45	<.05	5.8	--	184	71	--	7.8	3	NYSDH; ABS <0.01
318-531-2	do.	r10	1/23/63	--	.02	--	--	--	--	--	62	--	3.2	--	7.1	--	80	29	--	7.0	0	NYSDH
318-537-1	Sand	2	11/19/62	--	.0	--	--	--	--	--	71	--	2.6	--	.5	--	64	6	--	6.8	4	NYSDH
318-548-1	Sandstone	r120	7/10/56	6.1	.78	.28	37	5.0	4.1		121	9.1	9.8	.0	.0	141	113	14	239	7.2	5	USGS
			8/ 7/57	7.8	1.5	.45	28	6.3	8.0		104	9.6	13	.1	.2	129	96	11	227	6.6	5	USGS
			9/ 3/58	6.7	5.2	.47	37	10	9.2		166	13	3.0	.1	.1	152	134	0	271	6.7	5	USGS
			8/17/60	7.1	.87	.85	14	4.0	5.3		55	11	5.1	.2	.4	81	52	7	135	6.2	2	USGS
			7/26/61	5.4	40	1.1	31	10	6.9		146	2.5	7.8	.2	.1	142	119	0	265	6.4	2	USGS
			8/ 2/62	4.2	13	1.1	22	6.8	5.8		90	19	1.8	.2	.0	109	83	9	178	7.0	3	USGS; sample taken after chlorination.

Table 6.--Chemical analyses of ground water from selected wells and springs in the Eastern Oswego River basin (Continued)

Well or spring number	Water-bearing material	Depth of well (feet)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness (as $CaCO_3$) Calcium, magnesium	Hardness (as $CaCO_3$) Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Remarks
319-543-1	S & G	r86	11/ 4/64	--	0.32	--	--	--	--	--	--	13	1.8	--	--	100	86	0	187	7.8	--	USGS
319-626-2	do.	r42	4/18/63	--	.10	--	--	--	--	--	162	--	47	--	0.4	--	184	51	--	7.5	28	NYSDH; ABS <0.01
320-546-1	Sandstone	r85	11/ 4/64	7.7	.10	0.02	21	34	67	5.6	210	46	12	0.05	.06	272	66	0	451	7.9	2	USGS
321-623-1	do.	r75	11/13/64	10	.62	.06	56	11	156	7.7	188	16	269	.3	.0	642	185	30	1,190	7.9	2	USGS
321-625-2	do.	r100	10/ 8/41	--	.16	--	--	--	--	--	140	--	20	--	--	--	136	21	--	7.6	--	NYSDH
322-543-1	S & G	r18	12/17/63	--	.04	.01	--	--	--	--	89	--	1.0	--	2.4	--	86	13	--	8.4	2	NYSDH
324-524-1	L. Shale	r280	8/16/60	6.9	.10	.18	16	3.9	9.9		75	9.4	3.3	.1	2.0	89	56	0	151	7.1	6	USGS
			7/26/61	7.3	.38	.0	19	4.0	4.1		75	6.0	3.2	.1	.5	83	64	3	145	6.5	2	USGS
			8/ 1/62	6.7	.58	.07	17	3.7	5.1		68	7.5	2.1	.1	2.1	80	58	2	134	6.7	3	USGS; sample taken after chlorination.

What causes the variation in dissolved-solids content? Where does the more highly mineralized water occur? Once we know the answers to these questions we can go on to look more closely at the specific characteristics of ground water in the basin. An easy way to find out about the mineralization of water is to measure its ability to conduct electricity. Water that contains no dissolved minerals is an extremely poor conductor of electricity. The more the dissolved minerals in water, the higher its electrical conductance.

Figure 36 shows the relationship of specific conductance (the reciprocal of electrical resistance) of water in the basin to dissolved solids.

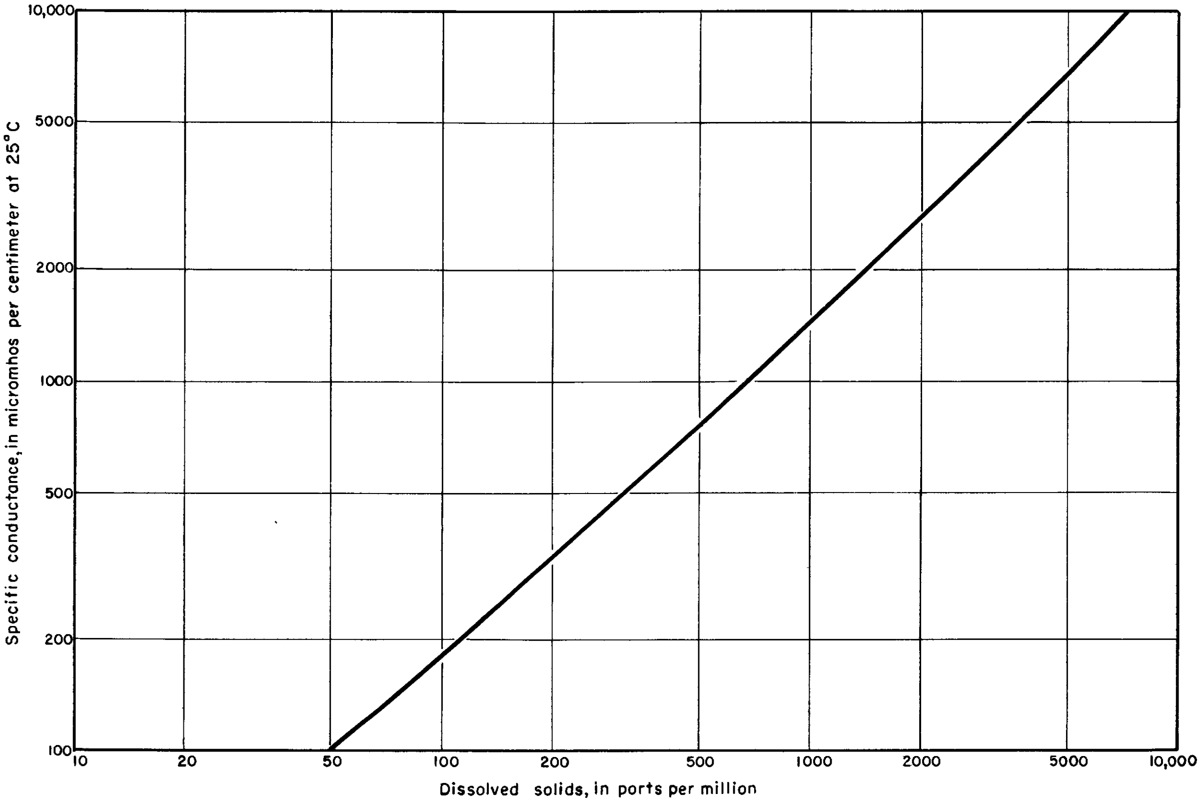


Figure 36.--Electrical conductance is a measure of the dissolved-solids content of water.

By measuring the conductivity of streamflow at many places along many streams we can determine the areal distribution of dissolved solids. During fair weather, water in the streams represents ground water that has been discharged from the ground-water reservoir. Such streamflow therefore represents an integrated sample of ground water from a relatively large area. Figure 37 is a map showing the dissolved-solids content of shallow ground water based on the conductivity of streamflow and chemical analyses of water from selected wells.

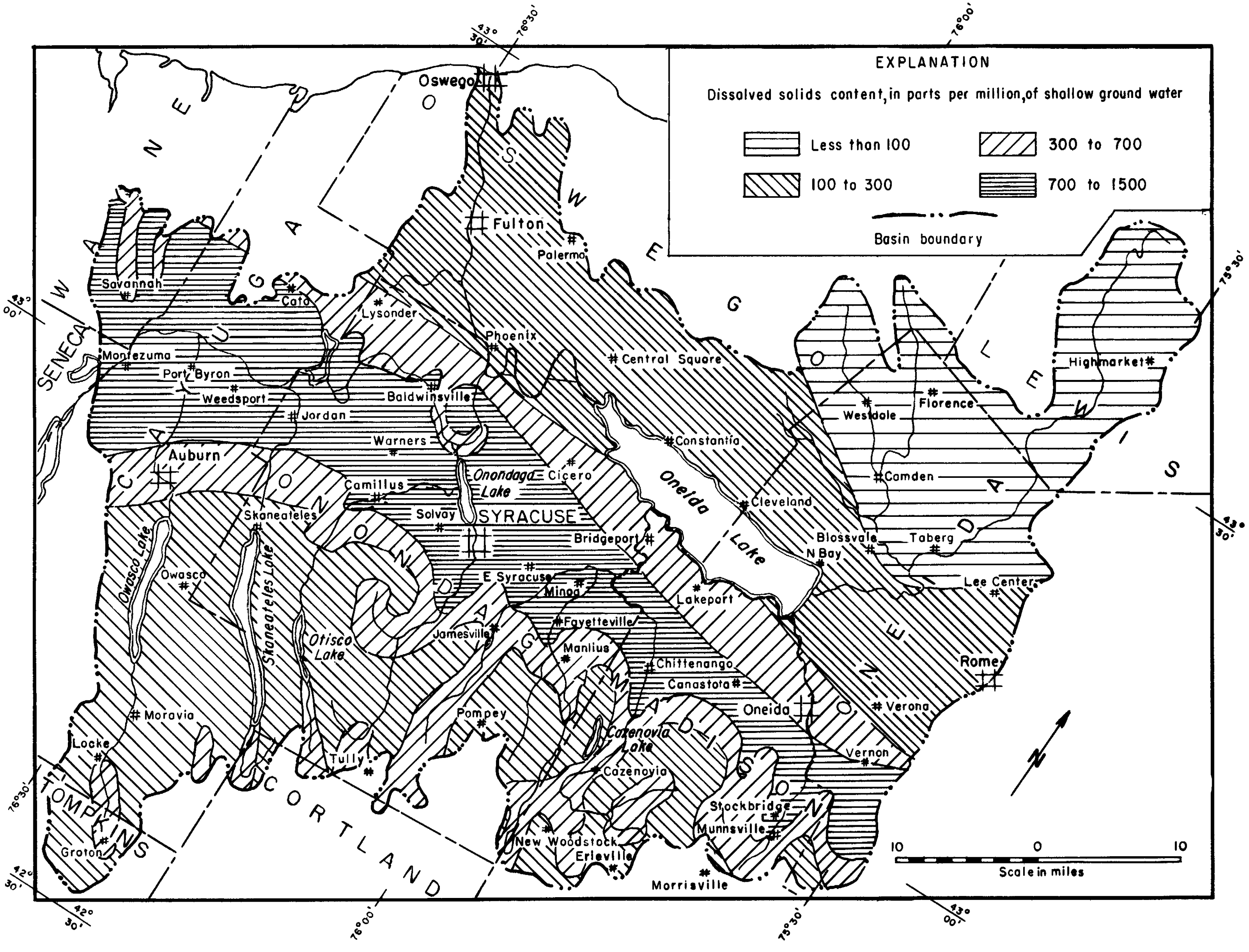


Figure 37.--The concentration of dissolved solids in shallow ground water ranges from less than 100 to 1,500 ppm.

The patterns shown in figure 37 have a general similarity to the outcrop pattern of the bedrock units (pls. 3 and 4). Each of the bedrock units is composed of a distinctive group of minerals with varying degrees of solubility. The middle shale unit contains large amounts of gypsum (calcium sulfate), one of the most soluble minerals found in nature. The most highly mineralized fresh water in the basin occurs along the outcrop of this unit. Because the limestone and dolomite units are composed of relatively soluble minerals, (calcium carbonate and calcium magnesium carbonate), moderately to highly mineralized water (300 to 700 ppm) occurs along their outcrop areas. The upper shale and sandstone-shale units are relatively insoluble although they do contain some soluble layers of limestone. Ground water in the outcrop areas of these units is moderately low in dissolved solids (100 to 300 ppm). The sandstone and lower shale units are composed almost entirely of relatively insoluble minerals. Ground water with the lowest dissolved-solids content in the basin occurs along their outcrop.

When we say that figure 37 shows the dissolved-solids content of shallow ground water, we are talking about water in the first 50 or 100 feet of saturated material, which may include both unconsolidated deposits and bedrock. Over most of the basin, water enters the ground-water reservoir through the unconsolidated deposits and then moves into the bedrock. Around many streams, lakes, and swamps, water moves from the bedrock into the adjacent unconsolidated deposits. It is this interchange of water that keeps the quality of water in the unconsolidated deposits similar to the quality in the underlying bedrock. Also, the mineral composition of the unconsolidated deposits is similar to that of the underlying bedrock. The unconsolidated deposits are made up of material derived from the bedrock and generally this material has not been transported very far.

Where glacial transport of the unconsolidated deposits has been extensive, the quality of the ground water is likely to be affected. For example, the unconsolidated deposits in the major valleys in the southern part of the basin are composed mostly of fragments of the limestone unit. This material was carried southward into the outcrop area of the upper shale unit by the glaciers. The quality of the ground water in these valley areas is more closely related to the water in the limestone unit than it is to the water in the surrounding upper shale unit.

The effect of the mineral composition of the unconsolidated deposits on the quality of ground water is also felt in the outcrop area of the sandstone unit. The western and southeastern parts of the outcrop area lie in the Ontario-Mohawk Lowland. During the Ice Age, a glacier moved out of the basins now occupied by Lake Ontario and spread over this lowland. The glacier carried small amounts of limestone fragments from bedrock units that crop out north of the basin. Some limestone fragments are therefore found in the unconsolidated deposits that resulted from this glacial advance. On the other hand, the unconsolidated deposits in the north-eastern part of the sandstone unit outcrop area are free of limestone fragments. These deposits resulted from the movement of relatively

"clean" ice that moved over, rather than around, the Tug Hill Upland. The presence of these two types of unconsolidated deposits has caused the variation in chemical quality noted along the outcrop area of the sandstone unit.

HARDNESS

Hardness is the chemical characteristic most familiar to water users. Hard water is recognized by its soap-consuming tendency and by the formation of scale in hot-water heaters, pipes, and cooking utensils. In this basin calcium and magnesium are by far the most abundant of the elements that cause hardness. Two types of hardness occur in the basin. If the calcium (Ca) or magnesium (Mg) is associated with carbonate (CO_3), the hardness is said to be "carbonate" or "temporary." We use the term "temporary" because when this type of water is heated the (Ca, Mg) CO_3 becomes an insoluble precipitate and forms a scale, leaving the water soft. If the calcium or magnesium is associated with sulfate (SO_4) the hardness is said to be "noncarbonate" or "permanent." This type of hardness generally does not form scale unless the water is boiled but its effect on the lathering ability of water is the same as carbonate hardness. In addition, water with a high noncarbonate hardness often acts as a laxative.

The principal sources of calcium and magnesium in the basin are the dolomite, middle shale, and limestone units and the unconsolidated deposits derived from these units. The dolomite unit is composed almost entirely of calcium-magnesium carbonate (Ca, Mg $(CO_3)_2$) and the limestone unit is composed primarily of calcium carbonate ($CaCO_3$). Water from these units is, therefore, likely to have hardness of the carbonate or temporary type. The middle shale unit contains layers of gypsum, which is a calcium sulfate mineral ($CaSO_4 \cdot 2H_2O$). Water from this unit is likely to have hardness of the noncarbonate or permanent type.

The relation of geology to water hardness is illustrated by the analyses of water from Chittenango Creek shown in figure 38. These samples were collected and analyzed by the New York State Department of Health (1957, p. 67). Figure 38 shows that as the stream flows across the outcrop of the upper shale unit the carbonate hardness of the water is relatively high because the unconsolidated deposits in the headwaters of the creek are limestone rich. When the stream flows across the outcrop of the limestone unit, the carbonate hardness of the water increases while at the same time the noncarbonate hardness remains very low. This is caused by ground water of calcium carbonate type that enters the stream from the limestone. When the stream flows across the outcrop of the middle shale unit, water of the calcium sulfate type enters the stream. The noncarbonate hardness of the water increases sharply while the carbonate hardness remains relatively constant.

In this report hardness is expressed as the theoretical concentration of $CaCO_3$, in ppm, even though there may be considerable $CaSO_4$ contributing to the hardness. That portion of the hardness that is caused by $CaSO_4$ is

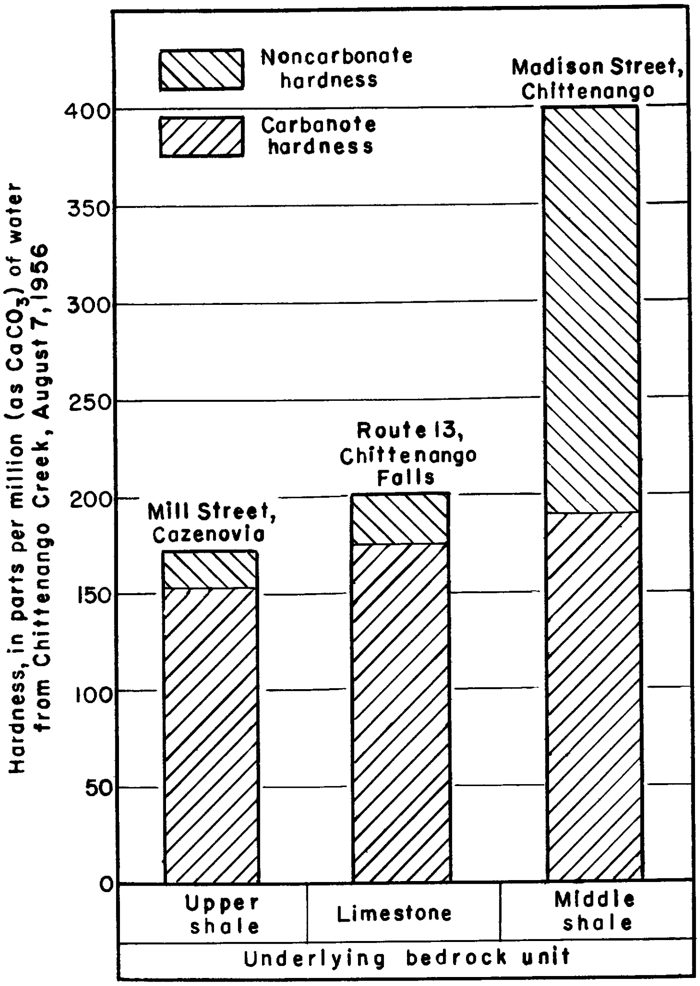


Figure 38.--Ground water discharging to streams affects the quality of streamflow.

shown in table 6 as noncarbonate hardness. The carbonate hardness may be determined by subtracting the noncarbonate hardness from the total hardness (called "calcium, magnesium hardness" in table 6). Many private laboratories report total hardness in "grains per gallon." This value can be converted to parts per million by multiplying by 17.12.

The hardness of nonsalty ground water in the basin ranges from about 50 to more than 2,000 ppm. Most of the samples of ground water collected in the basin had a hardness greater than 250 ppm. Water having a hardness of more than 180 ppm is generally considered to be very hard and would probably interfere with household use. Tolerance of water hardness, however, varies from person to person and usually depends on what the individual has become accustomed to.

Table 7 is a summary of water-hardness data for a representative sampling of wells in the basin. According to these data the owners of about half the wells regard their water supply as excessively hard, that is, they use water softeners or else they report that the hardness of the water interferes with laundering or cooking or leaves an annoying scale when heated. In many water samples the hardness is so great that $CaCO_3$ may precipitate in a glass left standing overnight.

Table 7.--Occurrence of hard water in the Eastern Oswego River basin

Water-bearing unit	Total number of wells	Wells in which excessively hard water is reported: Number of wells	Wells in which excessively hard water is reported: Percent of total
Upper shale	123	40	32
Limestone	23	18	78
Middle shale	101	79	78
Dolomite	21	10	48
Sandstone-shale	42	13	31
Sandstone	45	11	24
Lower shale	8	2	25
All bedrock units	363	173	48
Sand and gravel	224	138	62
Sand, silt, and clay	46	19	41
Till	94	51	54
All unconsolidated deposits	364	208	57
All sources	727	381	52

The reported hardness of water in the bedrock units (table 7) is about what we would expect based on the mineral composition of the various units. Also, if we were to look at the areal distribution of hardness in the unconsolidated deposits, we would find that hard water occurs wherever the deposits were derived from carbonate- or sulfate-bearing bedrock. Because carbonate rock fragments are relatively resistant to glacial erosion, they comprise much of the coarser fraction of the unconsolidated deposits. For this reason, hard water is more prevalent in till and sand and gravel than it is in the finer grained sands, silts, and clay.

In general, water is likely to be excessively hard wherever it contains more than 300 ppm of dissolved solids (fig. 37). Water in the areas where the dissolved-solids content ranges from 300 to 700 ppm is likely to have hardness of the carbonate type. Wherever the dissolved solids are greater than 700 ppm water is likely to have hardness of the noncarbonate type. Because $CaSO_4$ is more than 100 times as soluble as $CaCO_3$, it is readily dissolved and thus occurs in higher concentrations than does $CaCO_3$.

The sulfate content of ground water in the area underlain by the middle shale unit, based on analyses in table 6, has a median value of about 1,000 ppm. In water from the bedrock units, the sulfate content ranges from 439 to 1,790 ppm, and in water from the unconsolidated deposits it ranges

from 345 to 1,160 ppm. The U.S. Public Health Service (1962, p. 32-34) reports that water containing more than 250 ppm of sulfate generally has a noticeable taste and that water with more than 600 ppm of sulfate usually has a laxative effect. It seems likely that most of the ground water with an excessive noncarbonate hardness is also likely to exceed the limit of 250 ppm of sulfate recommended for drinking water by the Public Health Service.

Domestic water supplies may be softened, by the use of any of several commercially available home units. Large-capacity units are also available for the softening of public and industrial supplies. Most water-softening units are of the zeolite ion-exchange type. A zeolite is a mineral that although insoluble in water, does provide a surface on which ions (electrically charged atoms or groups of atoms) can collect. The softening process involves the exchange of the hardness-producing ions of calcium and magnesium for the nonhardness-producing sodium (Na) ion from the zeolite. An example of the chemical reaction involved in the exchange of calcium for sodium is:

$$Na_2Z \ + \ CaCO_3 \longrightarrow Na_2CO_3 \ + \ CaZ$$

in which Z represents the zeolite. A similar reaction exchanges magnesium for sodium. Softened water resulting from these reactions contains sodium carbonate or sodium sulfate rather than the calcium-magnesium carbonate or calcium sulfate of the untreated hard water. Periodically the sodium ions carried by the zeolite are used up. They can be replaced by passing a brine (NaCl) solution through the softener. The chemical reactions involved in regeneration of the zeolite are:

$$CaZ \ + \ 2\ NaCl \longrightarrow Na_2Z \ + \ CaCl_2,$$

and

$$MgZ \ + \ 2\ NaCl \longrightarrow Na_2Z \ + \ MgCl_2$$

The calcium magnesium chloride is flushed out and the sodium charged zeolite is as good as new.

Softening is effective in removing carbonate and noncarbonate hardness, however the sulfate content of the water is unchanged. Water with a non-carbonate hardness may therefore still have an unpleasant taste and act as a laxative even after softening. There are ion-exchange units that are capable of removing sulfate but these are generally considered to be too expensive for ordinary use.

Many naturally occurring clay minerals have properties similar to zeolites and can produce ion-exchange reactions. This natural reaction is the same as the reaction that occurs in home softening units; however, natural softening in the Eastern Oswego River basin generally removes a relatively small percentage of the hardness producing ions.

Softened water contains relatively more sodium and potassium and less calcium and magnesium than unsoftened water. Figure 39 is a diagrammatic representation of the principal ions present in water from two wells in the basin. The shape of the trapezoid formed by each analysis indicates whether

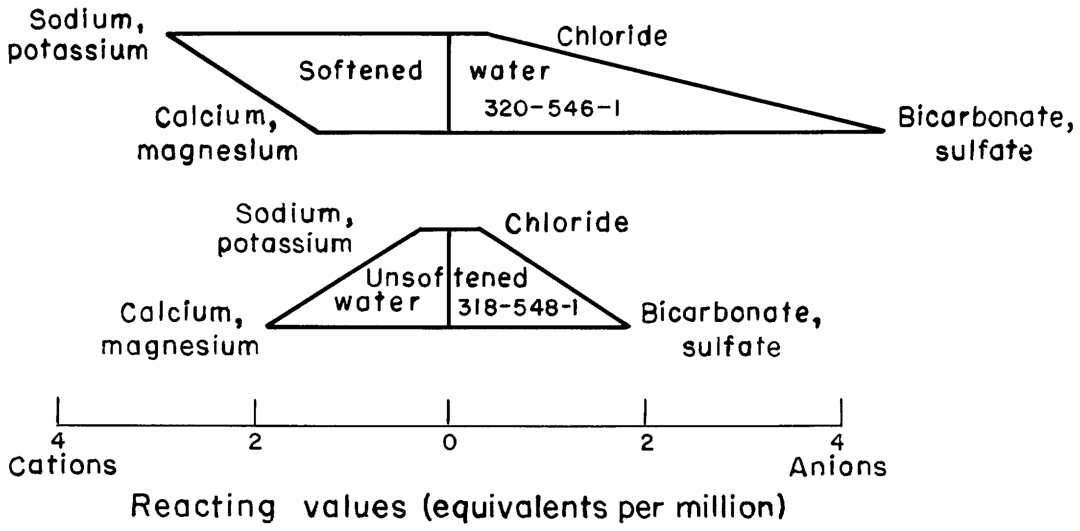


Figure 39.--Softening by ion exchange alters the chemical composition of water.

the water has been softened. The analysis of water from well 318-548-1 plots symmetrically about the center line; the sodium and potassium in the water balances with the chloride, and the calcium and magnesium balances with the bicarbonate and sulfate. This is characteristic of unsoftened water. On the other hand, the assymetrical shape of the analysis from well 320-546-1 indicates that there is more sodium and potassium than is needed to combine with the chloride, and not enough calcium and magnesium to combine with the bicarbonate and sulfate. This analysis, therefore, suggests that calcium and magnesium have been removed from the water and replaced by sodium; in other words, the water has been softened. Actually, the water from well 320-546-1 is not treated, it is an example of naturally softened water. According to the analyses in table 6, natural softening occurs in water from the upper shale (251-620-1), middle shale (302-627-2), sandstone-shale (308-536-1), and sandstone (320-546-1) units. Additional sampling may reveal even more widespread natural softening in the basin.

As a byproduct of both the natural and artificial softening process, the sodium content of water is increased. For many persons on salt-free diets the concentration of sodium in softened water may be intolerable. This is discussed in more detail in a later section, "The sodium problem."

IRON AND MANGANESE

Water with even relatively low concentrations of iron or manganese may stain fabrics, painted surfaces, and porcelain plumbing fixtures. The Public Health Service (1962, p. 43, 47) recommends that the iron content in water supplies not exceed 0.3 ppm and that manganese not exceed 0.05 ppm.

About one-third of the wells for which analyses are shown in table 6 yield water with an iron content greater than 0.3 ppm; about one-fourth of the wells yield water with a manganese content greater than 0.05 ppm. Similarly, based on data obtained from more than 700 well owners in the basin, iron-manganese staining is a problem in about 25 percent of all domestic supplies. Table 8 is a breakdown of these data according to water-bearing units.

Table 8.--Occurrence of iron and manganese in ground water from the Eastern Oswego River basin

Water-bearing unit	Total number of wells	Wells in which excessive iron and/or manganese is reported: Number of wells	Wells in which excessive iron and/or manganese is reported: Percent of total
Upper shale	123	27	22
Limestone	23	4	17
Middle shale	101	47	47
Dolomite	21	3	14
Sandstone-shale	42	10	24
Sandstone	45	10	22
Lower shale	8	1	12
All bedrock units	363	102	28
Sand and gravel	224	60	27
Sand, silt, and clay	46	8	17
Till	94	11	12
All unconsolidated deposits	364	79	22
All sources	727	181	25

Iron and manganese occur most frequently in water from the middle shale unit but are also relatively common in the remainder of the water-bearing units. The red and green color of many of the rock layers in the middle shale are an indication of the presence of iron-bearing minerals. Iron-bearing minerals also occur in the red beds of the sandstone-shale unit; in fact, iron ore has been mined from this unit in parts of Oneida County. It seems likely that, if more data were available, iron staining would be found to be a more frequent problem with water from the sandstone-shale unit. Manganese is much less abundant than iron and occurs principally as an impurity associated with the iron-bearing minerals.

Iron and manganese can be removed by a combination of chlorination and filtration, by aeration and settling, or by the addition of phosphate to the water. Commercial units are available which make iron-manganese removal practical for domestic supplies.

FLUORIDE

There has been considerable publicity in recent years about the effect of fluoride on teeth. It has been proven that fluoride, when present in the proper concentration in drinking water, helps prevent tooth decay. On the other hand, when too much fluoride is present, teeth may become discolored. The acceptable level of fluoride concentration depends on the daily intake of water. Because liquid intake is largely controlled by air temperature, the acceptable fluoride concentration in water varies from place to place. For the temperature range of the Eastern Oswego River basin, the U.S. Public Health Service (1962, p. 8) recommends that the fluoride concentration in drinking water should range between 0.8 and 1.5 ppm. Continued use of water with greater fluoride concentration will probably cause mottled teeth (endemic fluorosis) in children up to 12 years of age.

The fluoride content of nonsalty ground water in the basin is almost always below the beneficial range (0.8 to 1.5 ppm). The only exceptions are likely to be in water supplies derived from the middle shale unit. Water from well 302-627-2 (table 6) has a fluoride content of 2 ppm. Concentrations of fluoride above the beneficial range doubtless will be associated with extremely hard water with a high sulfate content. Most likely, intake of such water will be restricted because of its objectionable taste. For this reason it is believed that neither harmful nor beneficial effects are associated with naturally occurring fluoride in the basin.

NITRATE AND POLLUTION

Nitrogen does not occur naturally in any of the rocks of the basin. It is, however, a common constituent of organic compounds. Nitrate (NO_3) is the end product of the decomposition (oxidation) of organic nitrogen. Nitrates are introduced into the ground by nitrogen-fixing plants and bacteria, plant debris, animal wastes, and organic and most inorganic fertilizers. Thus, the source of nitrates is shallow, either from the soil or from shallow waste-disposal systems.

The nitrate content of ground water in the basin ranges from 0.0 to 44 ppm. As is shown in figure 40, the nitrate concentration in ground water is generally greater at shallow depths. This is in agreement with the shallow source of nitrogen-rich material. Also, most of the shallow wells shown in figure 40 are dug wells that draw upon the upper-most part of the ground-water reservoir. This is the part of the reservoir that directly receives water that has moved through the soil zone, and water from waste-disposal systems, especially cesspools and septic tanks, barns, and fertilized fields. The median concentration of nitrate in water from dug wells in the basin was about 4 ppm. The median concentration in water from drilled wells was less than 1 ppm. Springs and dug wells less than 5-feet deep had a median nitrate concentration of more than 5 ppm.

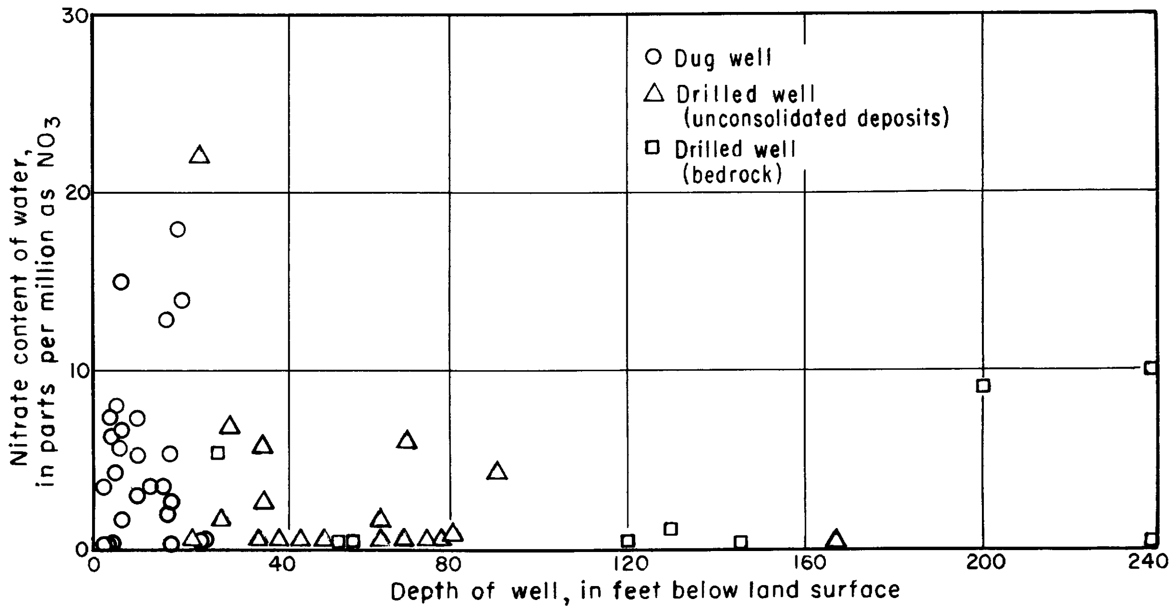


Figure 40.--Higher nitrate concentrations are generally found in shallow ground water.

The use of water containing more than about 45 ppm of nitrate in the preparation of feeding formulas for infants may cause methemoglobinemia ("blue-baby"), a serious and often fatal illness (U.S. Public Health Service, 1962, p. 47-50). Adults are apparently unaffected by nitrates in water. It would be well to check the nitrate content of any domestic water supply (particularly from a dug well) if the water is to be used for infant feeding.

Nitrates, because of their association with the decomposition of organic wastes, are an indicator of ground-water pollution. Relatively low concentrations of nitrate, perhaps 5 ppm or less, may result from the natural decomposition of plant tissue or the metabolism (life activity) of certain bacteria. Higher concentrations of nitrate are usually indicative of man-made pollution, either from fertilizers, or more commonly from cesspools or septic-tank wastes.

In order to avoid pollution, water wells should be developed as far as possible from sources of pollution, and always so that polluted ground water cannot move toward or into them. For example, barnyards are a common and yet a particularly poor location for wells. Also, dug wells should be adequately constructed, with impermeable fill around the upper part of the well and a concrete cover, as shown in figure 23, to protect against surface pollution. Because shallow ground water generally moves in the same direction as the slope of the land surface, wells should be developed upgrade from sources of pollution. There are some cases where it is almost impossible to avoid pollution. Shallow ground water under unsewered hamlets or housing developments, or even in cities where leaky

sewers exist, may be grossly polluted. Because of the density of septic tanks in unsewered residential areas it is often impossible to place a well so that it will be free of pollution.

Pollution may be minimized by sealing off the shallowest ground water and developing water from deeper aquifers by means of drilled wells. Generally, the nitrate content of deeper ground water is reduced by dilution with nonpolluted water. As is shown in figure 40, this may not always be the case, particularly if the aquifer is a relatively permeable bedrock unit such as the limestone or middle shale units. The two deep wells shown in figure 40 yield water with a nitrate content of 9 and 10 ppm are drilled in the middle shale and limestone units. Solution has widened the openings in these rocks so that they act as pipelines, transmitting water with very little mixing or dilution.

More significant than the nitrate content are the micro-organisms that may be present in polluted water. Water polluted by cesspools or septic-tank wastes may contain bacteria that can cause dysentery, typhoid fever, infectious hepatitis, and other water-borne diseases. Disease-causing viruses may also be transmitted by polluted water. Properly located and constructed wells generally yield water that is free of harmful organisms. If pollution is suspected, however, the State or County Health Departments should be consulted.

Chlorination can make all but the most grossly polluted water fit for human consumption. Chlorination, however, does not remove nitrate from water, nor is there an economical method known for doing so. Where a water-supply system is known or suspected to be polluted it is suggested that an alternate source be used, especially for infant feeding.

HYDROGEN SULFIDE

Although the term "hydrogen sulfide" may be unfamiliar to many water users, the quality this compound imparts to water is easily recognized by everyone. Hydrogen sulfide (H_2S) is a gas that, when present in even minute amounts, gives water a rotten-egg or sulfurous odor. Water containing hydrogen sulfide is commonly referred to as "sulfur water." Hydrogen sulfide generally is not determined in laboratory analyses because the gas rapidly escapes after sampling by routine methods. However, because it is so easily detected, data on the presence of hydrogen sulfide were obtained from the owners of more than 700 representative wells in the area. These data are shown in table 9.

The origin of the relatively widespread hydrogen sulfide is somewhat of a problem. Sulfate-reducing bacteria, which are often found in aquifers, can change gypsum ($CaSO_4 \cdot 2H_2O$) to hydrogen sulfide. Gypsum is found in abundance in the middle shale unit; however, ground water from this unit has a very low incidence of H_2S (table 9). Also, except for relatively minor occurrences in the dolomite unit and the lower part of the limestone unit, gypsum is not found in any other bedrock unit. Nevertheless, small

amounts of sulfate (SO_4), about 10 to 30 ppm, are found in most ground-water samples from the nongypsum bearing rocks (table 6). Of the wells sampled, only five yielded water with less than 5 ppm of sulfate. Hydrogen sulfide was noticed at two of these low-sulfate wells (251-620-1 and 308-536-1), and data were unavailable for the other wells (308-536-2, 314-529-1, and 318-548-1). The presence of hydrogen sulfide indicates that sulfate reduction may have taken place. Hydrogen sulfide is rare in the middle shale unit but the reason for this is obscure.

Table 9.--Occurrence of hydrogen sulfide (H_2S) in ground water from the Eastern Oswego River basin

Water-bearing unit	Total number of wells	Wells in which hydrogen sulfide is reported: Number of wells	Wells in which hydrogen sulfide is reported: Percent of total
Upper shale	123	25	20
Limestone	23	3	13
Middle shale	101	9	9
Dolomite	21	9	43
Sandstone-shale	42	11	26
Sandstone	45	9	20
Lower shale	8	4	50
All bedrock units	363	70	19
Sand and gravel	224	29	13
Sand, silt, and clay	46	1	2
Till	94	1	1
All unconsolidated deposits	364	31	9
All sources	727	101	14

Water from well 310-643-1 contained both sulfate (72 ppm) and very noticeable hydrogen sulfide. It seems unlikely, therefore, that sulfate reduction has taken place in this water. There are other sources of sulfur found in the basin besides sulfate. Many geologists have studied the bed-rock in the area and have reported the rather common occurrence of the mineral pyrite (FeS_2). (See, for example, Dale, 1953, p. 31, 36, and 37; Fisher, 1957, p. 11; Gillette, 1947, p. 163; and Zenger, 1965, p. 187 and 188.) Sphalerite (ZnS), another sulfur-bearing mineral, has been reported in the dolomite unit (Zenger, 1965, p. 188). Hydrogen sulfide is more common in those bedrock units in which the metallic sulfides are most frequently reported.

Formation of hydrogen sulfide from the metallic sulfides may occur in two ways. Sulfides will react with water and oxygen to form a weak sulfuric acid which, in turn, reacts with the remaining sulfides to produce hydrogen sulfide. This reaction requires oxygen, which generally is not available in ground water; the reaction is, therefore, probably of minor importance in the formation of hydrogen sulfide. Water entering the ground generally has had the opportunity to dissolve carbon dioxide, both from the atmosphere and from air trapped in the soil zone. The carbon

dioxide reacts with the water to form a weak carbonic acid. It is conceivable that in carbonate-poor areas such as the Tug Hill Upland, acidic ground water may react with the metallic sulfides to produce hydrogen sulfide and iron or zinc carbonates (siderite from pyrite, and smithsonite from sphalerite).

Regardless of its origin, hydrogen sulfide is a nuisance in water and its removal is generally desirable. Hydrogen sulfide reacts with oxygen to form water and sulfur; this reaction forms the basis for water treatment. Oxygen can be supplied by aeration, that is, by spraying the water into the air. This method is commonly used by large water users but is not practical for a domestic supply. The addition of chlorine to water releases oxygen and results in the breakdown of hydrogen sulfide. To be effective, however, a large amount of chlorine is required. A domestic chlorinator set to inject a relatively large amount of chlorine into the water, with subsequent removal of excess chlorine, represents the most efficient domestic treatment of sulfur water.

SALT WATER

It may surprise the casual visitor to learn that the Eastern Oswego River basin, although about 200 miles from the Atlantic Ocean, contains sizeable bodies of salt water. Even the native, who knows that Syracuse is often called the "Salt City," may be unaware of the extent and significance of salt water in the area. The adage "out of sight, out of mind" describes the situation. The salt water exists out of sight as salty ground water. It is only when salt water comes into sight in a water well that the full implications of living in or near the "Salt City" become clear.

SALT AND THE SYRACUSE AREA

Probably well before historical times the Onondaga Indians learned they could produce salt by boiling the water possessed by "evil spirits" found under the shores of Onondaga Lake. The first European to see the salt springs around the lake shore was Father Simon LeMoyne who passed through the area in August 1654. Permanent settlers did not move into the area until 1788, but by the following year about 500 bushels of salt were manufactured by boiling and the Syracuse salt industry was started. This was the first commercial inland salt produced in the New World.

From this meager beginning, salt production steadily grew until in 1862 it exceeded 9 million bushels per year. During much of this time, Syracuse salt accounted for about a tenth of the total salt consumed in the country. From 1787 to 1840, salt was also produced from brine springs at Montezuma. The discovery of rock salt at Saginaw, Michigan, about 1860 forecast the eventual end of the Syracuse salt industry. Encouraged by a temporary restriction of trade and shipping caused by the Civil War, a minor salt boom occurred throughout the area during the 1860's. Salt

companies were formed at Canastota, Port Byron, Central Square, Oswego, and Weedsport. All these ventures were doomed to failure, either because of insufficient concentrations of salt or because of insufficient markets.

By 1880, it became apparent that the brine-based Syracuse industry could not compete with the more efficient salt-mining industry in Michigan. In 1881, salt production began from mines in western New York. A number of test wells were drilled in the Eastern Oswego River basin in an effort to locate rock salt. It was not until 1888 that rock salt was located by the Solvay Process Company near Tully, about 17 miles south of the salt springs around Onondaga Lake. The only salt production in the basin at the present time is at the Tully site. Here, water is pumped down into the salt beds and the salt is dissolved. The brine is pumped back out of the ground, and flows through a pipe line to the Solvay Process plant. This plant is located on the west shore of Onondaga Lake not far from the site of the springs sighted by Father LeMoyne in 1654.

The "salt bell" that summoned the workers to cover the evaporating pans in case of rain no longer rings in Syracuse. But local names, such as Salina (Latin for salt), Liverpool (named for a famous salt-producing city in England) and Geddes (named after an early salt manufacturer), recall the reason why Syracuse is called the "Salt City."

SALTY GROUND WATER

Salty ground water found in the Eastern Oswego River basin is of the sodium-chloride type; that is, the predominant dissolved mineral is sodium chloride (NaCl), common table salt. The determination of the chloride content of water is a relatively simple procedure whereas the determination of sodium is much more complicated. For this reason, the chloride content of water serves as an index of its total salt content. The U.S. Public Health Service (1962, p. 33) recommends that drinking water should not contain more than 250 ppm of chloride. Above this limit most people will detect a salty taste. The chloride content of ground water in the basin ranges from less than 1 to more than 61,000 ppm (more than three times the chloride content of sea water). However, as shown in figure 41, most ground water is well below the threshold of taste.

The areas where salty ground water is likely to occur are shown in plates 1, 2, 3, and 4. Salt water is much more prevalent in the bedrock, but in places it also occurs in the unconsolidated deposits. Not all wells drilled in the areas outlined on the maps will yield salty water. To avoid drilling a salt-water well, we must learn as much as possible about the distribution of the salty water. To do this, however, we must first understand the origin of salt water. Once we are familiar with its origin we cannot only explain the observed distribution of salty water but also predict other areas where it is likely to occur.

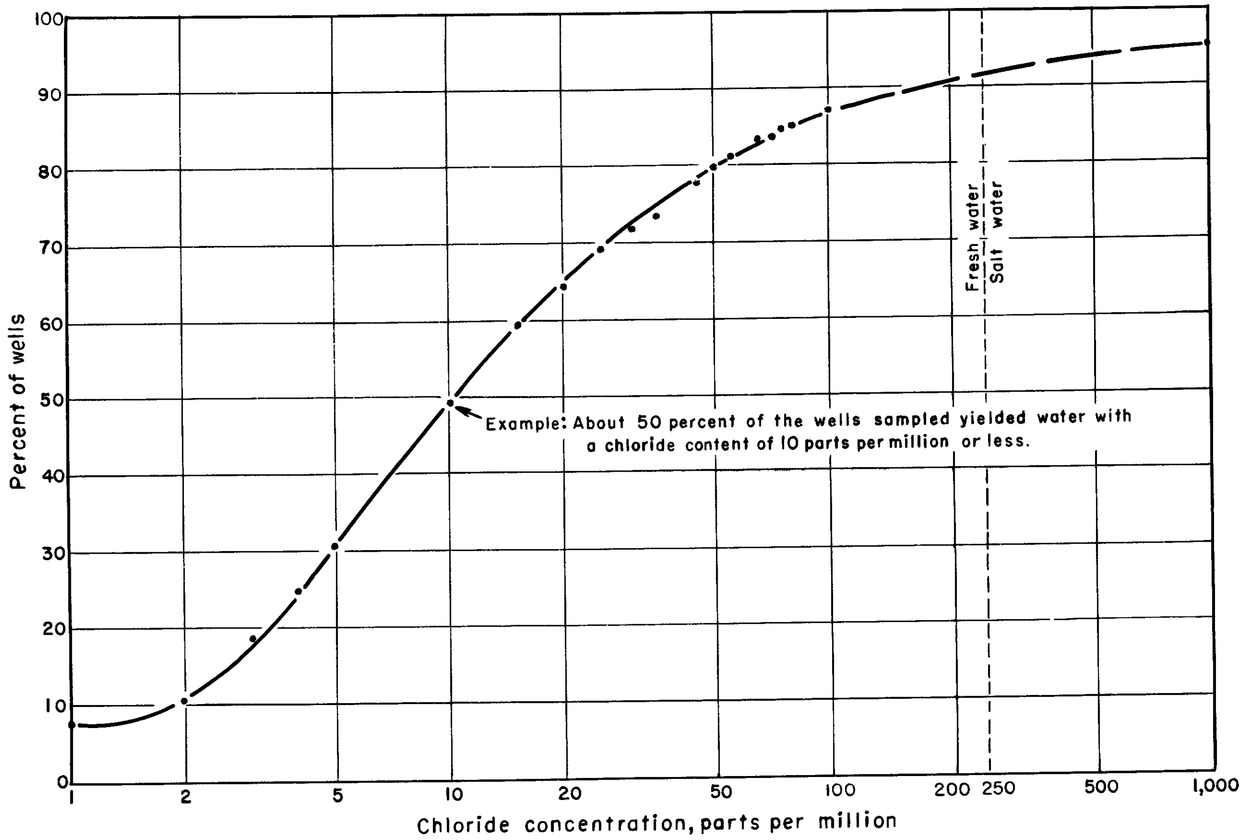


Figure 41.--The chloride content of water samples from 720 wells shows that most ground water in the Eastern Oswego River basin is fresh.

Origin of salty ground water

The source of most, if not all, of the water in the ground is precipitation (rain and snow). Samples of precipitation have been collected at Savannah, in Wayne County, as part of a monitoring program of precipitation quality throughout the Northeast. The chloride concentration of rainfall at Savannah has consistently been less than 1 ppm. Evaporation of part of the rainfall doubtless increases the chloride content of the water that enters the ground. The maximum chloride concentration of this water is probably less than 5 ppm. In figure 41 we see that about 70 percent of the wells sampled in the basin yield water with more than 5 ppm chloride. There are three possible sources for the additional chloride:

1. Pollution;

2. layers of rock salt within the middle shale unit; and

3. salt water found at great depths within the rocks and residual from ancient seas.

Pollution.--We have already seen that pollution from wastes may add significant amounts of nitrate to ground water. In addition to nitrates, septic-tank effluent commonly contains about 80 ppm of chloride, but may contain much more, particularly if it includes water used to backwash home water softeners. Because septic-tank effluent becomes diluted when it mixes with water already in the ground, the chloride content of polluted ground water generally may be expected to be less than 80 ppm. Higher concentrations of chloride may result from contamination by road salt, largely sodium chloride. Each winter large amounts of salt are applied to roads to keep them free of ice and snow. Rain or melting snow eventually dissolves this salt and much of it enters the ground (the rest runs off and contaminates the streams). Ground water polluted by road salt may theoretically contain several thousand parts per million of chloride. However, because of dilution and mixing with fresh ground water, the highest measured chloride concentration in the basin believed due to road salt is 235 ppm.

Pollution is a factor contributing to the high chlorides found in ground water, particularly in the shallower parts of the ground-water reservoir. However, high chlorides in water from deep wells and in areas remote from road salting must be caused by something other than pollution. The tendency of salt water to occur in relatively well-defined broad areas (pls. 1, 2, 3, and 4) also suggests an origin unrelated to pollution.

Rock salt.--It would seem obvious that the salty ground water would, in some way, be related to the occurrence of layers of rock salt within the middle shale unit. The areal extent of this rock salt is well known because of the large number of deep exploratory wells that have been drilled. (See Kreidler, 1957.) In the Eastern Oswego basin the northern extent of the salt approximately coincides with the location of Route 20; deep wells drilled south of Route 20 will penetrate rock salt and those drilled north of Route 20 will not. This is shown diagrammatically in figure 42. There is ample geologic evidence that the salt was once more extensive; its postulated original extent is also shown in figure 42. North of its present limit, the salt has been dissolved by ground water. Ground water that contains dissolved rock salt would, of course, be salty; in fact, ground water adjacent to the rock salt is likely to be a saturated brine. We can assume, therefore, that the middle shale unit should, in places, contain highly salty ground water.

Water in the ground may, over long periods of time, move great distances. Figure 42 shows that the principal direction of ground-water flow in the Appalachian Upland is toward the valleys. However, the 100- to 200-foot thick zone from which the rock salt has been dissolved serves as a corridor for ground-water movement. Ground water follows the path of greatest permeability and the removal of several hundred billion cubic feet of rock salt from the middle shale unit doubtless has increased the permeability of the rocks remaining in or adjacent to the rock-salt zone. Thus, fresh water moves down and dissolves the rock salt from the middle shale unit and then discharges along a relatively narrow area near the northern edge of the Appalachian Upland.

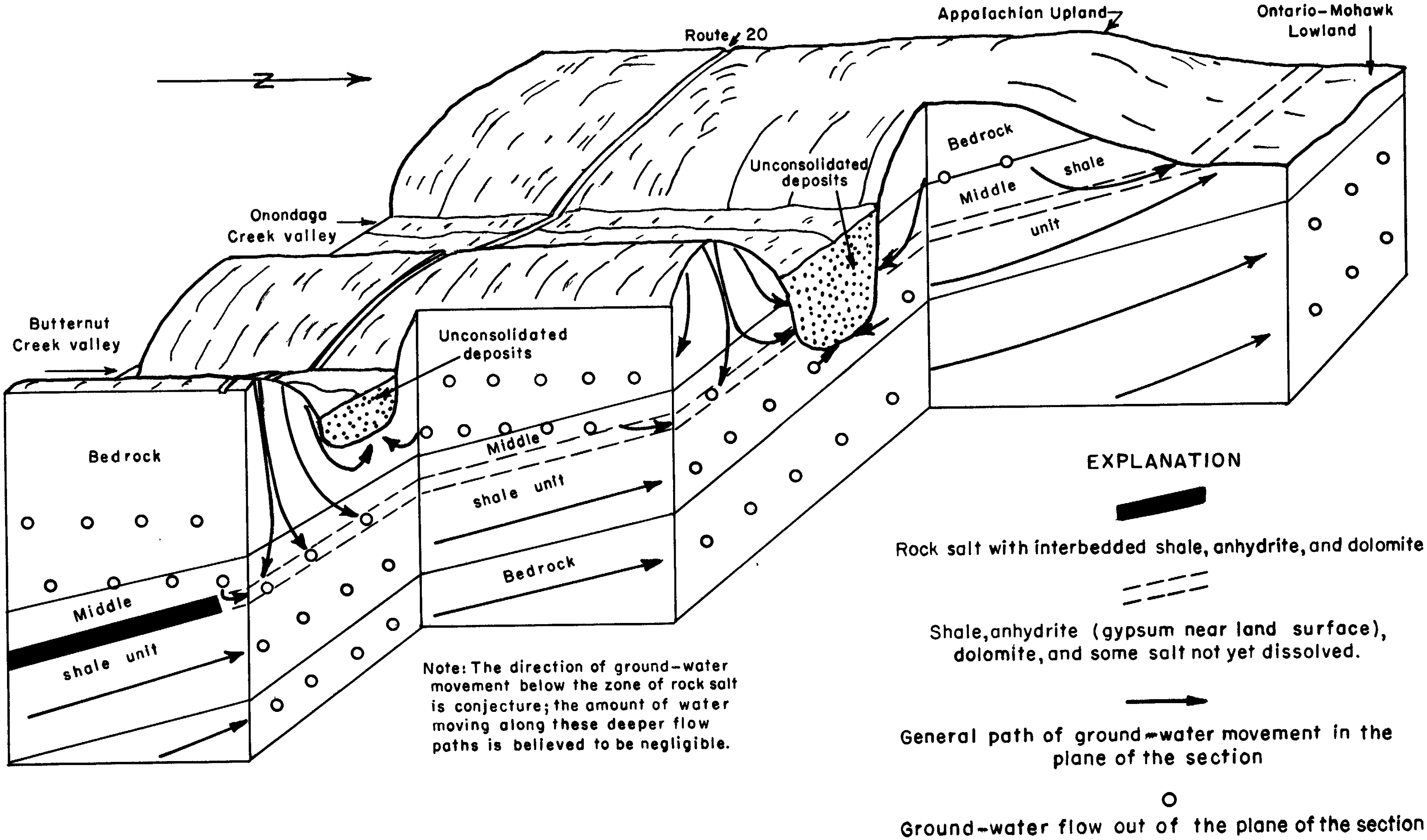


Figure 42.--Salty ground water from the middle shale unit moves toward a discharge area near the north edge of the Appalachian Upland.

The presence of highly salty ground water in Onondaga Creek valley is evidence of both the occurrence of brine in the middle shale unit and its movement along the zone of rock-salt solution. The bedrock underlying parts of the valley has been eroded to below sea level to form a trough-like depression. In places this trough has cut through the zone where rock salt has been dissolved but nowhere has it penetrated the rock-salt zone itself. Because the bedrock trough is partly filled with permeable deposits of sand and gravel, it acts as a huge collector well. Ground water from the bedrock moves into the sand and gravel and then moves toward a discharge area near Onondaga Lake. The water formerly used for salt manufacture at Onondaga Lake was pumped from these sand and gravel aquifers. The water had a chloride content of about 100,000 ppm (Clark, 1924, p. 184) which is about five times as salty as the ocean. Doubtless, some of the water that moved into the sand and gravel was fresh and some was salty. In order to account for chlorides of about 100,000 ppm, the salt water component from the bedrock must have been close to a saturated brine containing about 155,000 ppm of chloride (Hem, 1959, p. 111).

Figure 42 and the data from Onondaga Creek valley suggest that the salty ground water resulting from the solution of rock salt discharges only along a narrow area near the northern border of the Appalachian Upland. The occurrence of salt water underlying a widespread area around Oneida Lake and along the Oneida, Oswego and Seneca Rivers must be unrelated to the solution of rock salt. Additional evidence that this is true is provided by the occurrence of salt water in well 321-544-4, near Camden in the Tug Hill Upland. The regional direction of ground-water flow in the vicinity of the well is southward toward the Ontario-Mohawk Lowland. It is highly unlikely that ground water moves from the Appalachian Upland (where the middle shale unit and the salt beds are found) toward well 321-544-4. The occurrence of salt water in this well therefore supports an origin of salty ground water unrelated to the movement of brine from the middle shale unit.

Ancient sea water.--If the salt beds are not the source of the salty ground water underlying the Ontario-Mohawk Lowland, what is its origin? Let's digress for a moment and look at the occurrence of salt water beyond the Eastern Oswego River basin. Maps prepared by Feth and others (1965) show that much of the eastern half of the United States is underlain by salty (sodium chloride type) water, occurring within 500 feet of land surface. The Eastern Oswego River basin, in fact, constitutes a small part of a salt-water area extending from central New York, through western Pennsylvania, eastern Ohio, West Virginia and into Kentucky. Parts of this area are several hundred miles away from any rock salt; the presence of much of this salty ground water is generally attributed to deep salt water associated in some way with sea water that saturated the rocks when they were first formed. (See for example, Doll and others, 1960, p. 107; and Hendrickson and Krieger, 1964, p. 79-82.) Much of the salt water in the Eastern Oswego River basin is also probably related to deep salty ground water.

The bedrock underlying and adjacent to the large salt-water area, including the Eastern Oswego River basin, originated as sediments laid down in an ancient ocean between 300 and 400 million years ago. We can visualize that sea water must have been present in the pore spaces of the sediments, just as sea water is present in modern marine sediments. The way in which certain of the chemical constituents of the sea water have been retained in the sediments to produce the brines we find today is less readily understood. White (1965) reviews various theories of brine formation. For our purposes we may accept the fact that sodium chloride brine is almost always found in deeply buried rocks that originated as marine sediments.

After various geologic processes have brought the rocks containing salt water close to land surface, the rocks became part of the zone of circulating ground water. The brines then become diluted with fresh ground water and the resulting mixture slowly moves toward discharge areas. In this manner salt water is generally flushed out of the uppermost several hundred feet of bedrock. It is evident, however, that salt water has not been completely flushed out of the upper several hundred feet of bedrock underlying much of the Ontario-Mohawk Lowland. This is probably due to the effect of the layered rock salt in the Appalachian Upland on the deep pattern of ground-water movement. Although most rocks are rigid enough to maintain open fractures even under the great pressures found at depth, rock salt deforms plastically without rupturing. Therefore, rock salt does not maintain open fractures and is impermeable to water. (This explains why salt mines are dry, whereas most other mines are plagued by flooding.) Because it is impermeable, the rock salt in the Appalachian Upland, acting as a barrier, has prevented the development of a deep zone of circulating ground water.

We see in figure 42 that there may be a flow pattern beneath the rock salt that is unrelated to the upper flow pattern. The presence of brine in the rocks below the rock salt is well known from the records of oil wells in southern New York, Pennsylvania, and Ohio. An unknown, but probably extremely small amount of this deep salty water may be moving upward toward the discharge area in the Ontario-Mohawk Lowland. The occurrence of shallow salty ground water adjacent to surface-water bodies, which are ground-water discharge areas, suggests some upward movement of salt water from deeper parts of the bedrock.

The local recharge areas in the Ontario-Mohawk Lowland, shown in plate 3 to contain fresh water, are also underlain by salt water but at greater depth than under the discharge areas. Salt water is shown on the maps only where it occurs in the upper 100 feet of bedrock. The salt water found in well 321-544-4 (table 10) suggests that the Tug Hill Upland is also underlain by salt water at depth. This suggestion is supported by the presence of salt water in deep wells south of Watertown (outside the study basin), on the north flanks of the Tug Hill Upland.

Plate 4 shows that salty ground water occurs in the southern parts of several valleys in the Appalachian Upland. This salt water may be due either to deep salt water in the rocks above the salt beds or to the deep circulation of ground water down to the salt beds. Because of the

sometimes drastic changes water undergoes while moving through the ground-water reservoir, chemical evidence cannot be used to determine the origin of this salty water. Nor can it be used to determine the origin of the salt water in the remainder of the basin.

In summary, there are probably three types of salty ground water present in the basin:

1. Salt water caused by pollution;

2. salt water derived from the layers of rock salt in the middle shale unit; and

3. salt water moving upward from deeper parts of the bedrock.

The first type (from pollution) may be locally significant but is limited to the shallower parts of the ground-water reservoir, generally only to the unconsolidated deposits. The second type (from rock salt) occurs along the border between the Appalachian Upland and the Ontario-Mohawk Lowland, and may possibly occur at depth throughout other areas of the Appalachian Upland. The third type (from deep salt water) occurs at shallow depths along streams, lakes, and rivers in the Ontario-Mohawk Lowland, at greater depth throughout the remainder of the Ontario-Mohawk Lowland, and probably also underlies the Tug Hill and Appalachian Uplands at depth.

How to get a fresh-water supply

Plates 1, 2, 3, and 4 show the areas where wells are likely to yield salt water. However, it is commonly possible to get a fresh-water supply in these areas because some fresh water is generally found above the salt water. The fresh-water zone results from small-scale ground-water flow patterns superimposed on the regional patterns. Figure 43 is a generalized close-up view of part of the Ontario-Mohawk Lowland showing the local circulation of fresh water and its relation to the underlying salt water. We can see from this diagram that fresh-water wells in the salt-water areas must be shallow, generally less than 50 feet deep and almost always less than 100 feet deep. Salt water is likely to be relatively closer to land surface near streams and other discharge areas because of the upward movement of the underlying salty ground water.

As a rule, the salt content of ground water at any site increases with increasing depth. The records of wells 308-538-1 and 308-538-2 illustrate this point. These wells are only 50 feet apart; the first is 81 feet deep and yields water with a chloride content of 5 ppm and the second is 172 feet deep and yields water with 310 ppm of chloride. Such cases are quite common in the basin.

The first step in planning a ground-water supply in the areas underlain by salt water relatively near the surface is to determine if the salt water occurs only in the bedrock or whether it is in the unconsolidated deposits as well. This can be done by examining plates 1 or 2 and 3 or 4.

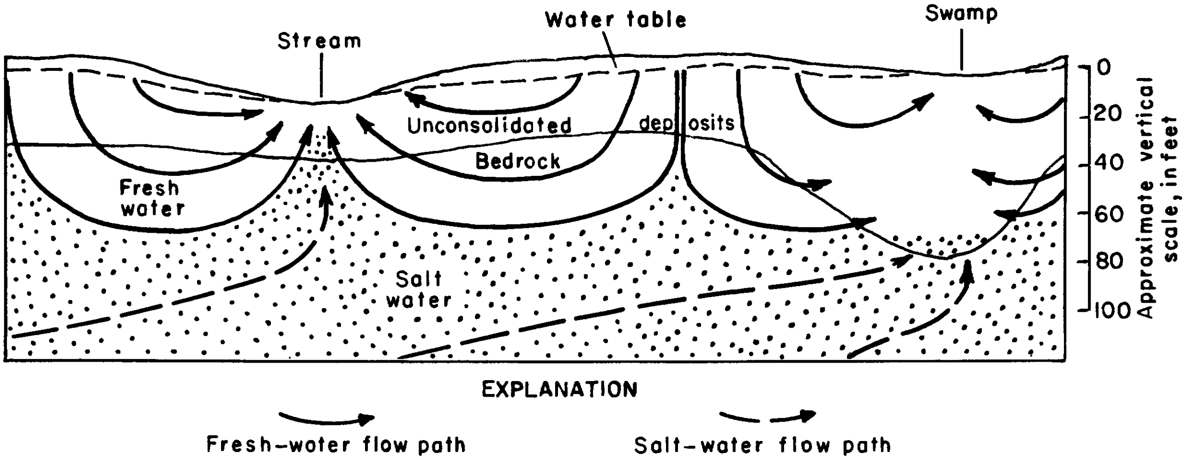


Figure 43.--Local ground-water circulation produces a relatively thin fresh-water zone above the salt water.

If salt water occurs only in the bedrock, the safest method of getting fresh water is, of course, to drill a well in the unconsolidated deposits. If the unconsolidated deposits consist of till or clay and silt, it may be necessary to drill into the underlying bedrock. Because the fresh-water zone generally extends only about 10 to 20 feet into the bedrock, every effort should be made to finish the well as shallow as is possible. It is better to be content with a shallow, low-yielding fresh-water well rather than to drill deeper and end up with a higher yielding, salt-water well.

In some localities salt water occurs both in the bedrock and the unconsolidated deposits. This generally occurs where sand and gravel has filled depressions in the bedrock surface. Salt water from the bedrock moves into the sand and gravel deposits which act as ground-water drains. The bedrock valley shown in figure 43 is typical of several in the Ontario-Mohawk Lowland that contain salty ground water in the unconsolidated deposits. For example, well 306-552-2 taps a buried sand and gravel aquifer filling a bedrock depression south of Oneida Lake. This well yields water with a chloride content of more than 500 ppm. Some valleys in the Appalachian Upland also contain salty ground water in the unconsolidated deposits. This condition, as it exists in Onondaga Creek valley, is illustrated in figure 42. Wherever salt water occurs in the unconsolidated deposits, no fresh water is present in the bedrock. However, shallow wells drilled into the unconsolidated deposits will usually yield small supplies of fresh water. Continuous large-scale pumping, at a rate of more than about 50 gpm, will generally produce salty water.

THE SODIUM PROBLEM

Low-salt diets are commonly prescribed in the treatment and control of some illnesses, particularly congestive heart failure and many diseases of the kidneys. When we speak of a "low-salt" diet we really mean a low-sodium

diet. No definite limits have been set on the allowable sodium content of water for people on low-salt diets; limits prescribed by various researchers however, range from 10 to 115 ppm (McKee and Wolf, 1963, p. 258).

We have seen that sodium chloride salt is present in all ground water in the basin. Sodium and chloride occur in a relatively fixed ratio, approximately two parts of sodium for every three parts of chloride. Figure 44 shows a graphical presentation of this relationship. A sodium content of 115 ppm corresponds to a chloride content of about 170 ppm, which is well below the taste threshold of 250 ppm of chloride. Using the chloride data from figure 41 and the relationship shown in figure 44, we can see that, of 720 wells sampled in the basin, about 40 percent are likely to have a sodium content greater than 10 ppm, and 10 percent are likely to have more than 115 ppm.

The straight-line ratio in figure 44 cannot always be used to determine sodium concentrations. Softening of hard water by the ion-exchange method adds sodium to the water but does not increase its chloride content. For every 100 ppm of hardness removed from water about 46 ppm of sodium are added. Thus, the removal of 250 ppm of hardness would increase the sodium content by 115 ppm, which is the suggested maximum allowable concentration in water used by persons on low-sodium diets. The two curves on the right-hand side of figure 44 show the sodium content of natural water after the removal of 100 and 500 ppm of hardness. It seems likely that prohibitive amounts of sodium may be added to water by natural as well as artificial softening.

Prudence dictates that persons on low-salt diets pay particular attention to the water they drink. Not only domestic supplies, but also several public supplies may contain excessive concentrations of sodium.

TEMPERATURE

Unlike water at land surface, which is affected by daily air-temperature changes, ground water has a relatively constant temperature and is generally within a few degrees of the mean annual air temperature (44° to 49°F in the Eastern Oswego River basin). Deep ground water may have somewhat higher temperatures because the temperature of the earth in most places increases about 1°F for each 100 feet of depth. This "thermal gradient," however, is generally not significant within 200 or 300 feet of land surface. Most ground water pumped from wells in the basin maintains a temperature within the range of 45° to 52°F. Ground-water temperatures fluctuate only 2° or 3°F annually; even shallow wells rarely fluctuate as much as 10°F during a year. The cool and constant temperature of ground water generally adds to its palatability, and in addition, makes it well suited to industrial needs.

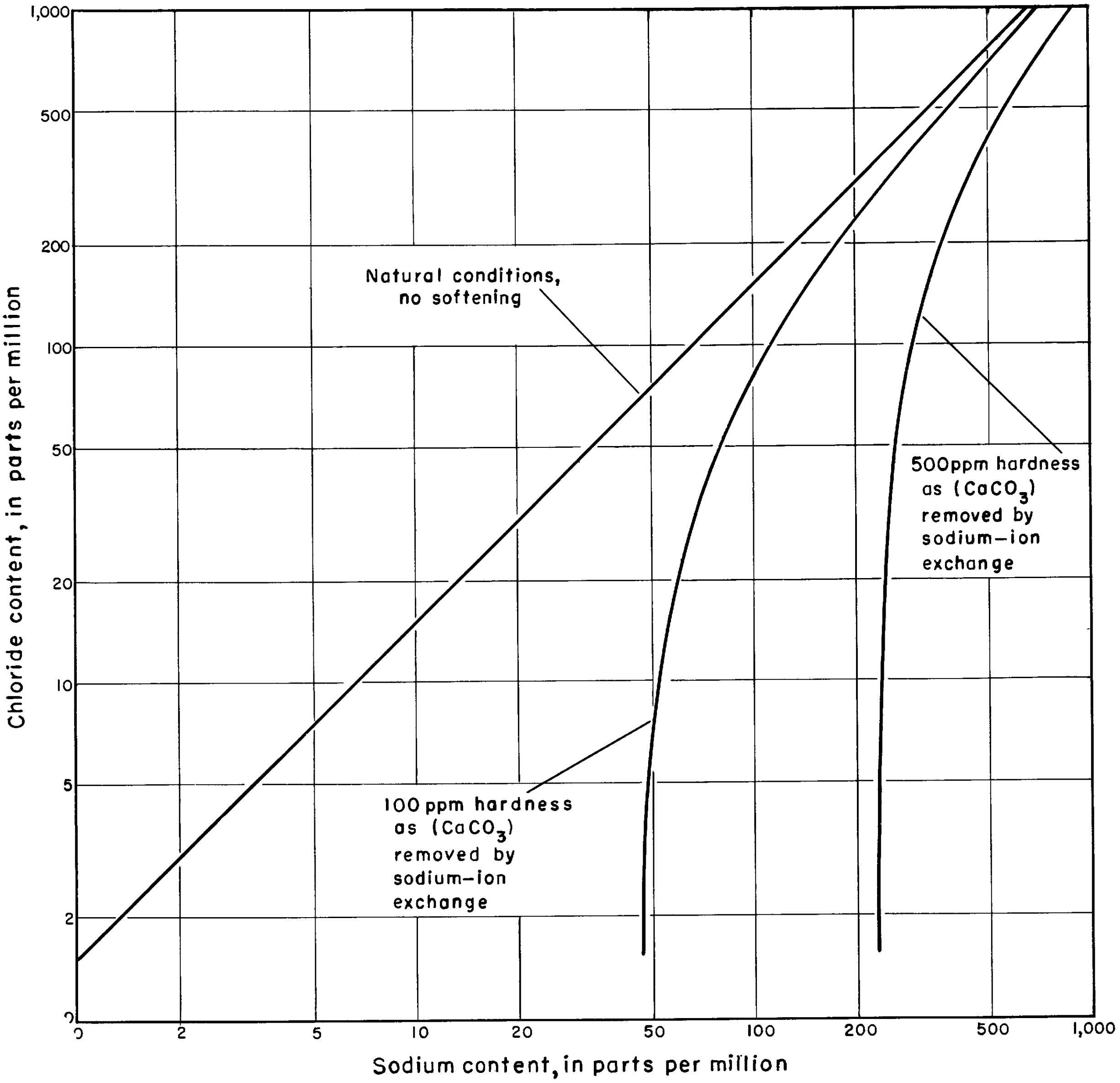


Figure 44.--The normal ratio of sodium to chloride is changed when water is softened by sodium-ion exchange.

RECOMMENDATIONS FOR FUTURE STUDIES

Future development of ground water in the Eastern Oswego River basin will proceed on two general levels: (1) small-scale development of domestic and farm supplies, and (2) large-scale development of public and industrial supplies. This report is adequate for the first level of development; it describes the best water-bearing material underlying each part of the basin and estimates the possibilities of obtaining adequate domestic and farm supplies. For the second level of development (public and industrial supplies), this report must be considered as little more than a reconnaissance study; it points out areas where large ground-water supplies are likely to be available and presents preliminary estimates of the quantities of water that may be obtained under conditions of maximum aquifer development. It must be stressed, however, that well and aquifer yields in this report are based on incomplete data. Future ground-water studies in the basin should be detailed investigations of specific areas that will determine the perennial yields of the major aquifers.

The perennial yield of an aquifer may be defined as the maximum rate of pumping that can be sustained for a prolonged period of no recharge without exceeding the available drawdown in the aquifer; provided also, that this discharge rate does not exceed the average rate of recharge to the aquifer. Thus, there are two factors affecting aquifer yield: (1) the physical response of an aquifer to pumping, and (2) the maximum recharge available to the aquifer. In order to predict the physical response of an aquifer to pumping, the hydraulic characteristics and geometry of the aquifer must be determined. This will require the construction of test wells and the analyses of aquifer tests. In order to predict the quantity of recharge available to an aquifer, the water balance of the aquifer and its tributary area must be determined. This will require monitoring of precipitation, ground-water levels, and stream discharge at carefully chosen sites.

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Table 10.--Records of selected wells in the Eastern Oswego River basin

Well number: See "Well-Numbering System" in text for explanation.

Year completed: a - about

Type of well: Drl - drilled
Dug - dug
Drv - driven

Depth of well: All depths below land surface.
a - about
r - reported
all others measured

Depth of casing: All depths below land surface.
r - reported
all others measured
drilled and driven wells - depth to bottom of casing or depth to top of slots or screen where present.
dug wells - depth to bottom of any casing that prevents infiltration of water.
Depth omitted for stone-curbed dug wells.

Diameter of well: Diameters of dug wells are approximate.

Depth to bedrock: All depths below land surface.
a - about
r - reported
all others measured

Water-bearing meterial: U Shale - Upper Shale Unit
Limestone - Limestone Unit
M Shale - Middle Shale Unit
Sand-Sh - Sandstone-Shale Unit
L Shale - Lower Shale Unit
S & G - sand and gravel

Altitude above sea level: estimated from topographic maps

Water level below land surface:
+ - above land surface
H - additional water-level measurements shown graphically in this report
r - reported
all other water levels measured

Chloride concentration: L - analysis made in U.S. Geological Survey laboratory
all other values obtained by field analysis

Use:
A - abandoned
C - commercial
D - domestic
De - destroyed
Dr - drainage
I - industrial
In - institutional
Ir - irrigation
O - observation
PS - public supply
S - stock
T - test
U - unused

Remarks:
anal - chemical analysis in this report
At - aquifer test data in this report
dd - drawdown; figure is in feet
gpm - gallons per minute
H_2S - noticeable odor of hydrogen sulfide
hard - occupant reports water is hard
inadequate - yield of well reported inadequate by owner
iron - water contains a relatively high concentration of iron, and commonly stains porcelain fixtures
salty - water tastes salty
scr - screen length, in feet
temp - temperature, in degrees fahrenheit, measured by U.S.G.S.
yield (e) - estimated yield
yield (m) - measured yield of pumping test or continuous pumpage
yield (r) - reported yield
> - greater than
< - less than

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
231-621-1	Leland K. Smith	1955	Drl	46	46	6	--	S & G	1,100	19.9	9/ 8/60	4	9/ 8/60	D	Yield (e) >6 gpm.
232-619-1	Robert Wright	1954	Drl	r340	--	6	--	U Shale	1,380	104.0	9/13/60	39	9/13/60	D, S	Yield (e) >2 gpm.
232-621-1	Milton Groves	--	Dug	13	--	24	--	Till	1,100	9.4	9/ 8/60	1	9/ 8/60	A	
-2	Owasco Valley Milk Producers Cooperative	1930	Drl	r120	--	8	--	S & G	1,040	--	--	4	9/14/60	D, I	H_2S; hard; yield (m) 75 gpm.
232-623-1	John Kocis	1955	Drl	r60	r30	6	r30	U Shale	1,300	r12	1960	4	9/ 8/60	D, S	Yield (r) 10 gpm.
233-622-1	Frank Smith	1905	Drl	63	25	6	25	do.	1,160	43.7	9/ 8/60	3	9/ 8/60	D	Yield (r) 6 gpm.
234-622-1	Jay Portzline	1958	Drl	r190	r90	6	r90	do.	1,060	r25	1958	6	9/14/60	I	Yield (m) 15 gpm.
235-622-1	Leo Tichenor	1959	Drl	r160	--	6	--	do.	1,220	--	--	20	9/13/60	D	Yield (e) 3 gpm.
-2	Village of Groton	1909	Drv	--	--	2	--	S & G	1,000	r4	1909	--	--	PS, U	One of six wells serving as an emergency water supply.
235-623-1	George Basl	1957	Drl	77	43	6	43	U Shale	1,440	10.0	9/14/60	6	9/14/60	D	Yield (r) 5 gpm.
236-619-1	Village of Groton	1948	Dug	15	--	48	19	Till	1,400	--	--	--	--	PS	Anal; one of 16 similar wells that yield a total of 200 gpm; well consists of collecting basin and 8-inch diameter tile lateral.
236-625-1	Warner Pierson	1900	Drl	36	20	6	20	U Shale	1,300	12.9	9/14/60	8	9/14/60	D	Hard.
237-623-1	Mineral Springs Restaurant	a1916	Drl	r2,250	--	6	--	--	980	+34.2	9/14/60	22	9/14/60	C, D	H_2S; flows 5 gpm; originally drilled as a gas well; bottom of well reported to be in salt layer.
238-621-1	Lukasz Rapij	1960	Drl	r53	--	5	--	U Shale	1,580	r23	1960	4	9/15/60	D	Yield (r) 3 gpm.
239-624-1	James Todd	--	Drl	r195	--	6	--	do.	1,180	--	--	12	9/15/60	S	Yield (e) >3 gpm.
239-628-2	Donald Phillips	--	Dug	25	--	24	--	Till	1,180	20.6	9/15/60	10	9/15/60	A	Hard; inadequate in summer.
240-625-1	Paul Austin	1960	Drl	89	89	6	--	S & G	800	19.2	9/15/60	16	9/15/60	D	Yield (r) 15 gpm.
-2	Clifford and William Wilcox	a1890	Drv	r85	r85	1 1/4	--	do.	760	+2.1	9/15/60	6	9/15/60	D	H_2S; flows 0.6 gpm.
242-615-1	Charles Redfield	1959	Drl	r87	r87	5	--	do.	1,320	r16	1959	6	7/24/61	D, S	Yield (r) 20 gpm.
-2	Arthur Hapgood	1956	Drl	r245	r200	6	r200	U Shale, sand	1,300	r60	1956	8	7/25/61	D	Yield (r) 15 gpm; water may come entirely from fine sand on top of rock.
242-618-1	Herman Crofoot	1944	Drl	86	30	6	30	U Shale	1,420	17.4	10/13/60	10	10/13/60	D	Yield (r) 20 gpm.
-2	Fred Beyea	1955	Drl	r95	r75	6	75	do.	1,520	4.0	10/13/60	16	10/13/60	D	Hard; yield (r) 7 gpm.
243-614-1	Herman Thornton	1959	Drl	r202	r28	6	r28	do.	1,340	r30	1959	15	7/24/61	D, S	Yield (r) 6 gpm; 2 gpm at 32 ft, 4 gpm at 202 ft.
243-617-1	Robert Lee	1961	Drl	r65	r46	6	r46	do.	1,560	r8	1961	4	7/25/61	D	Yield (r) 48 gpm with 5 ft dd; driller reports all water is from bedrock.
243-618-1	Floyd Hopkins	1957	Drl	r43	--	6	--	do.	1,610	+1.8	10/13/60	2	10/13/60	D, U	Temp 47.6, 10/13/60; flowing 1.2 gpm, 10/13/60.
243-627-1	Jerry Appel	1951	Drl	r75	r22	6	r22	do.	1,300	--	--	10	9/16/60	D	Yield (r) >10 gpm.
245-553-1	Arley Sartwell	1952	Drl	r119	r90	6	r90	do.	1,280	r3	1952	4,250 3,200	9/ 5/61 12/18/61	D	H_2S; hard; iron; salty; yield (r) 15 gpm.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
245-554-1	Minnie Benedict	--	Drl	44	44	6	--	S & G	1,280	20.6	9/ 5/61	10	9/ 5/61	D	H_2S; iron.
245-610-1	William and Johann Van Patten	1946	Drl	330	120	6	120	U Shale	1,340	77.5	6/ 6/61	310	8/15/61	A	Yield (r) 6 gpm; well was originally 100 ft deeper; water was very salty; bottom 100 ft plugged with concrete.
245-616-1	Edward Wanish	1960	Drl	r218	r217	5	--	S & G	880	+11.7	10/18/60	110	10/18/60	D	H_2S; yield (r) 10 gpm; flowing 2 gpm, 10/18/60.
246-553-1	Hazel Coon	1944	Drv	r16	r13	1 1/4	--	do.	1,320	--	--	6	8/31/61	D	Hard; iron; scr 3; yield (e) >6 gpm.
-2	S. H. Judd Co.	1952	Drl	r70	r70	6	--	do.	1,280	r12	1952	4	8/31/61	D, S	Hard; yield (r) >25 gpm; gravel poured into casing to keep sand out of water.
246-610-2	Leland and John Van Patten	1957	Drl	r327	r225	6	r225	U Shale	1,340	r30	1957	6	6/ 6/61	D, S	Yield (r) 36 gpm; very fine sand reported above bedrock.
246-619-1	William and John Byrne	1958	Drl	76	25	6	25	do.	1,820	27.2	10/13/60	14	10/13/60	D, S	Hard; iron; yield (e) 5 gpm.
246-631-1	Donald Myers	--	Drl	59	15	6	13	do.	1,320	13.8	9/16/60	--	--	D, U	Inadequate; well is drilled inside dug well; top of rock is cased off.
247-552-1	Llewellyn Powers	1947	Drl	r74	r74	6	--	S & G	1,300	r25	1948	6	9/ 5/61	D, S	Hard; yield (r) 30 gpm.
247-616-1	Edward Stillson	1946	Drv	r17	r16	1 1/2	--	do.	880	r10	1946	6	7/26/61	D	Yield (e) >4 gpm.
247-618-2	William Freeman	1960	Drl	69	32	6	32	U Shale	1,440	19.1	10/18/60	1	10/18/60	D	Yield (r) 6 gpm.
-3	Susan Matijas	a1930	Dug	6	--	72	--	Till	1,380	2.6	10/18/60	8	10/18/60	S	
-4	George Primanis	1960	Drl	r275	--	6	a25	U Shale	1,160	57.1	7/26/61	8	7/26/61	D	H_2S; yield (r) 12 gpm.
247-620-1	George Marr	1954	Drl	75	32	5	32	do.	1,580	34.0	10/17/60	10	10/17/60	D	Hard; yield (r) 6 gpm; well is drilled inside dug well.
-2	John Anderson	--	Dug	14	--	36	--	Till	1,520	6.3	10/18/60	55	10/17/60	D	Hard.
247-621-1	Gerald Adams	1957	Drl	r95	r15	6	r7	U Shale	1,380	r10	1957	4	10/17/60	D	Yield (r) 2 gpm.
247-629-1	Josephine Messenger	1951	Drl	13	13	6	--	S & G	820	5.6	6/23/61	4	6/23/61	D	Hard.
247-631-1	Glenn Hilton	1956	Drl	r100	r26	6	r26	U Shale	1,250	r9	1956	2	9/16/60	D	Hard; iron; yield (r) 3 gpm.
248-552-1	Rose Narsasian	1959	Drl	r79	r25	6	r25	do.	1,320	r35	1959	9	9/ 5/61	D	Yield (r) 30 gpm.
248-553-1	Stephen Goga	a1956	Drl	r135	r135	5	--	S & G	1,285	+6.5	10/26/60	3	10/26/60	D	Temp 47.2, 10/26/60; yield (r) 15 gpm; flowing 4 gpm, 10/26/60.
-4	Thomas Hershell	a1947	Drl	r166	r150	6	r150	do.	1,285	+2.0	9/ 5/61	4	9/ 5/61	D	Hard; iron; flowing 0.5 gpm, 9/5/61; source of water is gravel from 148 to 150 ft.
-8	Gertrude Dunlap	1954	Drl	r211	--	5	a100	U Shale	1,285	1.7	9/13/61	470	9/13/61	D	Salty; yield (r) 13 gpm.
248-607-1	Charles Banner	a1910	Drl	r120	--	6	--	S & G	1,260	r20	1959	29	10/31/60	D, S	Hard.
248-610-1	Walter Clay	--	Dug	14	--	24	--	Till	1,360	13.9	9/16/59	--	--	D	Hard; inadequate in summer.
248-613-1	Donald Doody	a1950	Drl	r260	r200	6	--	Clay	880	--	--	--	--	A	Inadequate; bottom of hole is open in clay.
248-627-1	Gerald Shaw	1960	Drl	173	10	6	10	U Shale	1,260	46.5	10/18/60	14	10/18/60	D	Yield (m) 2 gpm, dd 21 after 1 hour; water is cloudy.
249-553-1	Willis Means	1954	Drl	88	37	6	37	do.	1,320	51.3	8/31/61	4	8/31/61	D	Hard; yield (r) 5 gpm; sand on top of rock cased off.
-2	Ray Stafford	1959	Drl	64	64	6	--	S & G	1,285	9.4	9/ 6/61	--	--	D	H_2S; iron; yield (r) 15 gpm.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
249-604-1	George St. John	1959	Drl	39	39	6	--	S & G	1,240	17.6	10/28/60	10	10/28/60	D, S	Hard; iron; yield (r) 5 gpm.
249-608-1	Allied Chemical and Dye Corp.	--	Drl	r1,403	--	10	a400	---	773	--	--			I	Anal; H_2S; salty; temp 59.2, 11/12/64.
249-613-1	Raymond Cates	1960	Drl	r300	r140	6	r140	U Shale	900	--	--	--	--	De	Inadequate; clay on top of rock.
250-552-1	George Mabee	1955	Drl	263	100	6	100	do.	1,300	17.9	10/26/60	80	10/26/60	D	Hard; iron; yield (r) 4 gpm.
250-553-1	Arthur Larsen	a1953	Drl	r330	r300	6	--	Clay	1,280	82.3	8/30/61	--	--	A	Hard; inadequate; yield (r) <1 gpm; bottom of hole is open in clay.
-3	John Popek	a1950	Drv	r19	r16	1 1/2	--	S & G	1,300	3.9	8/31/61	4	8/31/61	D	Hard; iron; scr 3; water is sandy at times.
250-555-1	James Conway	1959	Drl	r125	r60	6	r60	U Shale	1,300	r20	1959	28	10/27/60	D	H_2S; iron; yield (r) 2 gpm.
-2	Bernal Ingersoll	a1940	Drl	r220	r190	6	r190	do.	1,320	r+1	1940	45	9/13/61	D	H_2S; yield (r) 5 gpm.
250-604-1	Joseph Sluzar	1960	Drl	r212	r210	6	--	Sand	1,080	r50	1960	4	10/28/60	D	Hard; iron; yield (r) 10 gpm; well drilled through clay with several thin layers of sand; source of water is sand from 210 to 212 ft.
250-607-1	Robert Haynes	a1910	Dug	8	--	48	--	Till	640	4.5	10/31/60	125	10/31/60	D	H_2S; hard; well is reported to be contaminated.
-2	Robert Snavlin	1951	Drl	r155	r155	5	--	S & G	620	r21	1951	195	10/31/60	D, S	Iron; yield (r) 20 gpm.
250-608-1	Henry Spencer	a1952	Drl	r250	r160	5	r160	U Shale	620	--	--	--	--	A	H_2S; salty.
250-612-1	Harold Henderson	a1860	Dug	10	--	42	--	Till	1,500	7.0	9/14/59	L2	9/14/59	D	Hard; inadequate at times.
250-614-1	William Martens	a1958	Drl	r200	r200	6	--	Clay	820	--	--	445	8/15/61	U	Inadequate; salty; flowing <1 gpm, 8/15/61.
250-630-1	Winslow Woodruff	a1942	Drl	r66	r10	6	1	U Shale	760	--	--	2	6/23/61	D	H_2S; flowing 1 gpm, 6/23/61.
250-634-1	John Gaglianese	1959	Drl	r96	r50	6	r60	do.	960	r20	1959	2	9/16/60	D	Yield (r) 10 gpm.
251-544-1	Clarence Abbuhl	1956	Drl	84	20	6	20	do.	1,660	4.4	10/26/60	10	10/26/60	D	
251-545-1	Erieville Water Comm.	--	Dug	18	7	--	7	do.	1,600	4.4	6/26/62	10	6/26/62	PS	Anal; well is a 30 by 15-ft excavation in rock.
251-550-1	Laurence Damon	1948	Dug	r167	r15	6	r15	do.	1,560	r20	1948	4	10/26/60	D, S	Yield (r) 20 gpm.
251-551-1	New Woodstock Water Dist.	--	Dug	6	6	72	--	S & G	1,360	--	--	8	6/26/62	PS	Anal; yield (m) 75 gpm.
251-554-1	Charles Cooney	--	Dug	2	2	72	--	do.	1,040	--	--	5	5/ 7/64	D	Hard; flowing <1 gpm, 9/19/60.
-2	Wayne Dow	1961	Drl	89	42	6	42	U Shale	980	8.6	9/19/61	130	5/ 7/64	D, S	H_2S; yield (r) 10 gpm.
251-555-2	Kenneth Skinner	1956	Drl	r315	r290	6	r290	do.	1,220	r150	1956	190	9/13/61	D	Iron; yield (r) 2 gpm; well was developed with dynamite; thick alternating layers of sand and clay reported to overlie bedrock.
251-613-1	Howard Flanagan	1959	Drl	30	r20	6	r20	do.	1,480	9.3	9/14/59	--	--	D	Yield (r) 1 gpm.
251-615-1	Edward Elbert	1946	Drv	r19	r16	1 1/4	--	S & G	800	--	--	4	6/ 6/61	D	Scr 2; temp 41.8, 6/6/61; yield (e) 5 gpm.
251-620-1	William Droppa	1955	Drl	r105	r14	6	r14	U Shale	1,100	r15	1955	13	9/19/60	D	Anal; H_2S; yield (r) 15 gpm.
251-624-1	Fred Hoyt	1961	Drl	101	65	6	65	do.	900	11.2	7/27/61			D	Yield (r) 8 gpm.
251-630-1	Robert Hoyle	1961	Drv	r24	r21	1 1/4	--	S & G	720	r6	1961	10	6/23/61	D	Hard; scr 3.
251-634-1	Edward Larkin	1945	Drl	r262	18	6	18	U Shale	910	--	--	8	9/16/60	D	Yield (r) 10 gpm; well was 149 ft deep, yield (r) <1 gpm; well deepened in 1958.
252-553-1	Richard DeBrucque	--	Drl	294	294	6	--	Silt	1,260	5.4	9/22/61	--	--	A	Inadequate.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well Number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
252-554-1	Spencer Foster	1960	Drl	r319	r319	6	--	S & G	960	+5.2	10/27/60	115	10/27/60	D	Yield (r) 15 gpm; flowing 1 gpm, 10/27/60.
-2	George Hand	1959	Drl	r102	r5	6	r5	U Shale	920	1.0	8/28/61	1,850	8/28/61	D	Anal; salty; yield (r) 2 gpm; flowing <1 gpm, 8/28/61.
-3	Michael Ryan	1953	Drl	r30	r30	5	--	S & G	960	r10	1953	5	8/28/61	D	Hard; yield (r) 5 gpm.
-4	D. E. Fletcher, Inc.	1958	Drl	190	190	6	--	do.	920	11.0	8/21/61	60	8/28/61	C, PS	Hard; supplies laundry and trailer park.
-6	Donald Edwards	--	Drl	r80	r10	6	r10	U Shale	960	--	--	160	9/19/61	D	Hard; inadequate August through September; iron.
252-556-1	Edward Heffernan	--	Dug	20	--	36	--	Till	1,540	3.6	9/ 1/61	--	--	D, U	
252-604-1	Earl French	1960	Drl	21	21	6	--	S & G	900	1.9	10/28/60	8	10/28/60	D	Hard.
-2	Ray Palmer	1957	Drl	290	r245	6	r245	U Shale	920	1.7	10/28/60	50	10/28/60	D	H_2S; yield (r) 5 gpm; water level controlled by overflow pipe; flowing <1 gpm, 10/28/60.
252-605-1	John Harrower	1951	Drl	r96	r96	6	--	S & G	860	r+3	1951	18	6/17/59	D	Hard; iron.
-2	J. D. Palmer	--	Drv	--	--	1 1/4	--	Sand	880	--	--	L2	6/17/59	D	Hard.
252-608-1	Fred Reed	--	Dug	r25	--	24	--	do.	520	r12	1956	30	10/12/60	D	Yield (r) 6 gpm.
252-609-1	Otis Miller	a1953	Drl	r153	r153	6	--	do.	540	r25	1957	325	10/12/60	D	Salty; yield (r) 10 gpm; flowed when first drilled; gravel poured into hole. Well drilled through clay with sand from 150 to 153 ft.
-2	Bernard DeVine	--	Dug	17	--	24	--	Clay	540	8.5	10/12/60	12	10/12/60	D	Hard; inadequate in dry seasons.
253-546-1	John Badertscher	1943	Drl	r143	r30	6	r30	U Shale	1,510	37.2	10/25/63	13	10/25/63	D, S	Hard; yield (r) 6 gpm.
253-547-1	Stanley Werbela	1945	Drl	r145	r145	6	--	S & G	1,440	--	--	10	10/25/63	D, S	Iron; flowed when first drilled.
253-549-1	Frank Bushneck	1958	Drl	r190	r150	6	r150	U Shale	1,370	19.5	10/23/63	14	10/23/63	D	H_2S; yield (r) 5 gpm.
-2	Johnson Brothers Lumber Co.	1952	Drl	r200	r45	6	r45	do.	1,440	r20	1952	55	10/24/63	C, D	Yield (r) 5 gpm; well was developed with dynamite.
253-550-1	Newton Sweetland	1944	Drl	r214	r85	6	r85	do.	1,320	--	--	120	10/23/63	D, S	H_2S; yield (r) 5 gpm.
-2	Robert Sweetland	--	Drl	r90	--	8	--	S & G	1,360	--	--	5	10/24/63	D, S	Hard.
253-552-1	H. Ludington and W. Richards	1943	Drl	r237	r237	6	--	do.	1,270	--	--	3	10/24/63	D	Hard; yield (r) 2 gpm; flowing <1 gpm, 10/24/63.
-2	Leslie Beals	1963	Drl	r165	--	6	--	U Shale	1,260	--	--	1,350	4/27/64	D	H_2S; salty; well flows.
253-554-1	Clifford Black	--	Drv	r15	r12	1 1/4	--	S & G	880	a10	1960	12	10/27/60	S	Hard.
-2	B. H. Tracy and Sons	1958	Drl	70	70	6	--	do.	880	+1.6	8/28/61	57	8/28/60	S	Hard; iron; yield (r) 7 gpm; flowing 1 gpm.
-3	Lionel Hickox	1946	Drl	80	30	6	30	U Shale	880	4.8	9/ 1/61	58	9/ 1/61	D	H_2S; yield (r) 3 gpm; flowed when first drilled; water from sand and gravel at 20 ft would not clear.
253-601-1	Frank Goodwater	a1956	Drl	r50	r30	8	r30	do.	1,660	--	--	L40	6/17/59	C, D	Hard.
253-602-1	Francis Carroll	a1910	Drl	r70	--	6	--	do.	1,460	26.0	6/17/59	L5	6/17/59	D, S	Drilled inside a 19-ft deep dug well; dug well dry 6/17/59.
-2	Leo Derry	--	Dug	11	--	18	ra13	Till	1,440	8.7	6/17/59	L19	6/17/59	D, U	Inadequate.
253-605-1	LaFayette Central School Dist.	1956	Drl	r300	r25	10	r25	U Shale	1,180	r90	1956	L3	6/17/59	In	Yield (m) 2.5 gpm, dd 100.
-2	Robert Sipfle	1958	Drl	r99	r21	6	r21	do.	1,200	r62	1958	L15	7/ 6/59	C, D	Yield (r) 9 gpm.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
253-606-1	Harold Irwin	1939	Drl	r80	r34	6	r34	U Shale	1,120	r50	1939	L45	7/ 6/59	D	Hard; yield (r) 10 gpm; drilled inside inadequate dug well.
-2	Fred Groth	1951	Drl	r168	r40	6	r40	do.	1,220	r+8	1951	L5	7/ 7/59	D	Hard; iron; yield (r) 11 gpm.
-3	LaFayette Central School Dist.	1937	Drl	r130	r56	10	r56	do.	1,115	r32	1963	--	--	In	Anal; hard; yield (m) 17 gpm, dd 38.
253-608-1	Charles Ortloff	a1938	Dug	7	--	36	--	Till	840	1.5	7/ 7/59	L2	7/ 7/59	D	Hard; temp 60.5, 7/7/59; yield (e) 2 gpm.
253-609-1	Herbert Kenyon	1948	Dug	r25	--	36	--	S & G	520	--	--	L3	7/ 7/59	D	Hard; iron.
253-613-1	Arthur Holbrook	--	Dug	17	--	30	--	Till	1,400	14.0	9/14/59	L.3	9/14/59	D	Hard; inadequate in dry summers; well dry September 1964.
253-614-1	New York State Natural Gas Corp.	a1932	Drl	160	43	6	42	U Shale	1,320	H,42.1	4/21/61	4	6/ 5/61	A, O	Yield (r) 30 gpm.
-2	Floyd Sears	--	Dug	20	--	18	--	Till	1,340	H,7.6	6/ 5/61	--	--	A, O	
253-617-1	E. J. Chapman	1935	Drv	r24	r22	1 1/4	--	S & G	800	r8	1960	14	6/ 5/61	D	Hard; iron; scr 2; temp 46.2, 6/5/61.
253-618-1	Paul Grassman	--	Drl	r87	r87	6	--	do.	800	+3.5	6/ 5/61	1	6/ 5/61	D	Temp 54.0, 6/5/61; flowing 2 gpm, 6/5/61.
-2	Leland Grandy	--	Drl	48	48	6	--	do.	800	1.6	8/16/61	8	8/16/61	D	Iron.
253-628-1	Thomas Obuch	1941	Drl	r252	r35	6	r35	U Shale	1,010	24.2	10/17/60	19	10/17/60	D, S	H_2S eliminated by raising intake pipe; yield (r) 18 gpm.
253-634-1	Francis Riester	1960	Drl	101	91	6	91	do.	750	42.4	10/13/60	14	10/ 1/60	D	Hard; yield (m) 4 gpm, dd >20.
254-534-1	Leon Nourse	1957	Drl	r252	r150	6	r150	do.	1,200	r50	1957	4	10/21/60	D, S	H_2S; hard; yield (r) 19 gpm.
254-554-1	Wilfred Carnahan	--	Drv	r20	--	1 1/2	--	S & G	840	--	--	6	10/28/61	D	Hard; iron.
-2	Ward Van De Bogart	1959	Drl	r130	--	6	--	U Shale	820	--	--	2	9/ 1/61	D	H_2S; iron.
254-555-1	Warren Stearns	--	Dug	4	--	36	--	Till	820	1.0	6/15/59	L9	6/15/59	D, S	Hard.
254-604-2	Paul Coon	1957	Drl	r67	r67	6	--	S & G	820	+9.0	7/10/61	14	7/10/61	C, PS	H_2S; iron; supplies laundry and trailer park; reported to flow 60 gpm; temp 50.0, 7/10/61.
-3	Fannie Buckley	a1955	Drl	r65	--	6	--	U Shale	780	+9.4	7/10/61	10	7/10/61	D	H_2S; temp 50.2, 7/10/61; flowing 4 gpm, 7/10/61.
254-610-1	Gunnar Ahlstrand	a1937	Dug	9	--	24	--	Till	550	3.5	10/22/63	--	--	D	
254-611-1	Francis Mooney	--	Drl	47	--	6	--	U Shale	640	36.6	7/ 7/59	L1	7/ 7/59	D	Inadequate in summer.
254-612-1	Beak and Skiff Apple Farms, Inc.	1957	Drl	r140	r7	6	r7	do.	1,060	r72	1957	L1	7/ 7/59	Ir	Hard; yield (e) 40 gpm.
254-613-1	Francis Hayden	1938	Drl	r112	r30	6	r30	do.	1,100	r30	1959	L4	9/12/59	C, D	Hard; yield (r) 28 gpm, dd 38; supplies home, gas station, and motel.
254-614-1	Kolomon Lukas	--	Dug	10	--	36	--	Till	1,040	5.0	7/ 7/59	L19	7/ 7/59	A	
254-617-1	Clifford Perry	a1948	Drl	446	r167	6	r167	U Shale	960	86.4	8/18/61	6	8/18/61	D	H_2S; yield (r) <1 gpm.
254-618-1	Donald Keppler	1960	Drl	r159	r159	6	--	S & G	840	r6	1960	1	6/ 1/61	D	Yield (r) 28 gpm.
254-619-1	Donald Weeks	1961	Drl	r71	r71	6	--	do.	780	--	--	2	6/ 6/61	D	Anal; yield (r) 20 gpm; water is sandy at times.
254-620-1	Frank and Harold Mills	--	Dug	19	--	144	19	Till	1,260	15.9	9/19/60	8	9/19/60	D	Hard; iron; supplies four families.
254-626-1	Frank Harris	1937	Drl	r215	r118	6	r118	U Shale	1,060	r30	1951	3	7/27/61	D, S	Hard; yield (e) >3 gpm.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
255-536-1	Lewis Smith	--	Drl	r125	--	6	--	Limestone	1,000	+5.5	10/ 5/60	3	10/ 5/60	D	H_2S; hard; iron; temp 50.2, 10/5/60; flowing <1 gpm, 10/5/60; drilled inside inadequate dug well.
255-537-1	Douglas and Leland Marshall	1940	Drl	r56	r56	6	--	S & G	1,200	--	--	9	10/ 5/60	D, S	Hard; yield (r) 15 gpm.
255-538-1	Charles Davis	1956	Drl	r175	r58	6	r58	U Shale	1,420	15.9	10/ 5/60	6	10/ 5/60	D, S	Yield (r) 6 gpm.
255-551-1	Village of Cazenovia	1945	Drl	r78	r68	10	--	S & G	1,200	r+8	1945	10	12/ 1/60	PS	Anal; hard; scr 10, gravel pack; yield (m) 310 gpm; reported to flow 150 gpm; one of two similar wells serving as village supply.
255-553-1	Frederick Ayling	1939	Drl	r196	--	6	a6	U Shale	1,220	r20	1956	L2	7/10/59	D	H_2S; yield (r) 1.5 gpm.
255-555-2	Floyd Holbrook	1954	Drl	180	6	6	6	do.	1,280	65.1	6/15/59	L5	7/10/59	C, D	Hard; yield (r) 5 gpm.
-3	Joseph Foley	1949	Drl	110	r73	6	r73	do.	840	16.1	10/27/60	11	10/27/60	D	H_2S; hard.
255-556-1	Andrew Phelan	--	Dug	18	--	36	18	Till	1,240	4.6	6/15/59	L10	6/15/59	D	Iron.
255-557-1	Clifton Waley	--	Dug	15	--	18	--	do.	1,240	8.8	6/15/59	L37	6/15/59	D	Hard; iron.
-2	Charles Frenzel	1955	Drl	r267	r22	6	r22	U Shale	1,240	r20	1955	L8	6/15/59	D	H_2S; yield (r) <1 gpm.
-3	Emmett Baumgartner	a1940	Drl	r90	r35	6	r35	do.	1,220	r20	1940	L28	6/17/59	D, S	Hard; yield (r) 5 gpm.
255-603-1	William Allen	1959	Drl	r38	r38	6	r38	Sand	740	r3	1959	3	7/10/61	D	Iron; yield (r) 30 gpm; well drilled through clay; source of water is sand from 37 to 38 ft.
255-605-1	Edward Klotz	a1954	Drl	53	6	6	r5	U Shale	1,440	8.6	6/28/61	20	6/28/61	D	Inadequate in summer 1960; yield (r) 8 gpm.
-2	Robert Van Rysewyk	1961	Drl	106	5	6	r2	do.	1,440	34.0	6/28/61	23	6/30/61	D	At; yield (m) 15 gpm, dd 18 after 5 hours.
-3	Fred Farwell	a1951	Drl	r135	12	6	r5	do.	1,440	78.5	6/28/61	19	6/28/61	D	Hard.
255-611-1	Harold Fenner	1959	Drl	r60	r33	8	r33	do.	620	r27	1959	4	6/27/61	D	Iron; yield (r) 10 gpm.
-2	Joseph Hass	1957	Drl	r195	r195	6	--	S & G	620	r100	1957	2	6/27/61	D	H_2S; iron; yield (r) 10 gpm.
-3	Ralph Betts	--	Drl	r130	r130	6	--	do.	600	101.6	6/27/61	1	6/27/61	D, S	H_2S; well drilled inside 62-ft dug well with 7 ft of water 6/27/61, indicates perched water table.
-4	Ernest Lathrop	1959	Drl	185	r185	6	--	do.	640	r86	1959	4	6/27/61	D	Hard; iron; yield (r) 18 gpm.
255-612-2	Winfred Tanner, Jr.	a1944	Drl	r140	r140	6	--	do.	600	--	--	L26	9/14/59	D	Hard.
-3	Elbert White	a1942	Dug	20	--	30	--	do.	600	16.9	9/14/59	L4	9/14/59	D	Hard; perched water table; well dug through 15 ft of sand and gravel and 5 ft of clay.
-4	Onondaga Central School Dist.	1934	Dug	6	--	--	--	do.	620	1.5	6/29/61	4	6/29/61	In	Anal; hard; yield (r) 180 gpm; well is 65 ft long, 6 ft across; probably perched water table.
255-616-1	Harold O'Ree	1950	Drl	51	r35	6	r35	U Shale	1,140	8.5	7/ 7/59	L9	7/ 7/59	D	Hard; yield (r) 10 gpm.
255-617-1	Edgar Norris	--	Dug	19	--	30	--	Till	1,120	9.9	7/ 8/59	L4	7/ 8/59	D, S, U	Hard; inadequate in summer.
255-619-1	Harold Masters	--	Dug	18	--	30	--	do.	1,050	10.4	7/ 8/59			D, S	Hard.
255-620-3	Fred and Gilbert Frost	a1949	Drl	r354	r70	6	r70	U Shale	1,160	r50	1949	L3	7/ 8/59	D, S	Hard; yield (r) 4 gpm.
-4	Philip Vile	1960	Drl	r97	r94	6	r94	S & G	780	--	--	10	6/ 1/61	D	Yield (r) 30 gpm; water reported from gravel on top of rock.
255-627-1	George Dobrovosky	a1955	Drl	504	47	8	47	U Shale, Limestone	1,050	15.3	7/27/61	26	7/27/61	A	Yield (r) 100 gpm; well penetrates upper 20 ft of Limestone Unit; dip sample taken for chloride analysis.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
255-628-1	Howard Turner	1937	Drl	r365	r30	6	r30	U Shale	1,030	r20	1937	4	10/17/60	D, S	Yield (r) 2 gpm.
256-555-1	Irving Carr	1954	Drl	r85	r58	6	r58	do.	840	r3	1954	2	10/27/60	D, S	Yield (r) 10 gpm.
256-607-1	John Vossler	1950	Drl	100	r12	6	r12	do.	940	44.5	9/ 9/59	L1	9/ 9/59	D	Yield (r) 4 gpm.
256-610-1	Isaac Henhawk	a1953	Drl	180	r180	6	--	S & G	620	155.4	6/27/61	2	6/27/61	D	Yield (r) 5 gpm.
256-612-1	Robert Greenway	1955	Drl	r142	r132	6	r132	Limestone	700	r66	1959	L1	9/12/59	D	Hard; yield (r) 14 gpm with little or no dd; water reported from 3-ft cavity in limestone at bottom of hole.
-2	Albert Palen	--	Dug	15	--	36	--	S & G	660	14.0	9/16/59	L34	9/16/59	D	Hard; inadequate in summer; perched water table.
256-614-1	Maurice Alexander	1950	Drl	17	r17	6	--	do.	520	12.7	9/16/59	L3	9/16/59	D	Hard; yield (r) 5 gpm, dd <1.
256-621-1	Ralph Bishop	1941	Drl	r175	r40	6	r40	U Shale	1,120	r150	1961	L4	7/ 8/59	D, S	Hard; yield (r) 8 gpm.
256-622-1	Raymond Dando	--	Dug	14	--	36	--	Till	1,060	9.1	7/ 8/59	L21	7/ 8/59	D, S	Hard.
256-623-1	A. J. Hoffman	--	Dug	20	--	36	--	do.	950	8.0	7/ 8/59	L22	7/ 8/59	D	Hard; inadequate in dry years.
-2	John Kovar	1958	Drl	r250	r28	6	r25	U Shale	1,010	r30	1958	L1	7/ 8/59	D	Yield (r) 4 gpm.
256-625-1	City of Syracuse	--	Drl	r58	r35	12	--	S & G	860	--	--	--	--	--	Yield (m) 625 gpm; dd 24 after 10 days; scr 25; sand and gravel from 18 to 58 ft underlies clay; well is used to maintain flow in Skaneateles Creek.
256-627-1	Edward Shepard	a1945	Drl	r400	r18	6	r18	U Shale	990	--	--	L3	7/ 9/59	Ir	Hard; yield (r) 5 gpm; yield did not increase below 150 ft.
-2	do.	1935	Dug	17	--	24	17	Till	990	7.0	7/ 9/59	L18	7/ 9/59	D	Hard.
-3	Robert Hall	1955	Drl	r283	r40	6	r40	U Shale	1,030	r30	1955	L1	7/ 9/59	D	Hard; yield (r) 6 gpm.
256-628-1	Earl Clark	1955	Drl	r75	r29	6	r29	do.	960	r1	1958	L74	7/ 9/59	D	Hard; iron; yield (r) 4 gpm.
256-630-1	Angelo Scozzari	1954	Drl	r111	r111	6	--	S & G	930	r24	1954	L1	6/ 4/59	D	Hard; yield (r) 9 gpm.
-2	E. A. Schillawski	a1939	Drl	r240	r100	6	r100	U Shale	920	r18	1959	L5	7/ 9/59	D, S	Yield (r) 5 gpm.
256-631-2	Morton Walker	a1911	Dug	r30	--	24	--	Till	840	--	--	L30	6/ 4/59	D	Hard.
-3	Michael Kany	a1953	Drl	r116	--	6	--	U Shale	820	--	--	L3	6/ 4/59	D	Yield (r) 4 gpm.
256-639-1	Joseph Pollard	a1930	Drl	r100	--	6	--	M Shale	520	r22	1956	L47	7/ 9/59	D, S	Hard.
-2	do.	--	Dug	22	--	36	--	Till	520	9.6	7/ 9/59	--	--	A	
256-640-1	Roy Schmelzle	--	Dug	18	--	24	--	do.	580	8.5	7/ 9/59	L12	7/ 9/59	D	Hard; inadequate in dry years.
-2	William Schmalzle	1953	Drl	r225	--	6	--	M Shale	580	r75	1953	14	9/30/60	D	Hard; iron.
-3	Clarence Hall	1947	Drl	r104	r23	6	r23	do.	500	r20	1949	65	9/30/60	C, D	Hard; iron; yield (r) >5 gpm; water for restaurant hauled.
256-641-1	James Mullen	1958	Drl	r100	--	6	--	do.	540	--	--	L5	7/ 9/59	D	Hard; iron; drinking water hauled.
256-642-1	Frank Bowers	--	Dug	30	--	48	--	Till	480	5.9	7/ 9/59	L4	7/ 9/59	D	Hard.
257-528-1	Richard Davie	1956	Drl	r197	r30	6	r30	Limestone	1,200	r6	1956	1	10/ 7/60	D	Hard; yield (r) >20 gpm.
257-534-1	Eastern Rock Products	1960	Drl	45	0	6	0	do.	940	35.3	10/24/60	--	--	Dr	At; yield (m) 4 gpm, dd 35.
-2	do.	--	Drl	139	10	6	10	M Shale	960	121.9	10/24/60	6	10/24/60	A	Inadequate to supply crushing plant.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
257-541-1	Walter Tucker	1954	Drl	r29	r29	6	--	S & G	1,300	7.0	10/ 5/60	32	10/ 5/60	D	Hard; iron; yield (r) 7 gpm.
-2	Fenton Bliss	1960	Drl	92	66	6	r65	U Shale	1,320	26.2	10/10/60	2	10/10/60	D	Yield (r) 5 gpm.
257-542-1	Elbert Hyers	--	Drl	38	r38	6	--	S & G	1,320	23.4	10/10/60	4	10/10/60	D	Yield (e) >3 gpm.
257-555-1	Hadwin Card	1960	Drl	102	102	6	--	do.	840	14.3	10/27/60	1	10/27/60	D	Yield 5 gpm.
257-604-1	Breezy Acre Trailer Village	1959	Drl	r89	88	6	--	do.	700	r+6	1959	1	10/28/60	PS	Hard; yield (r) 20 gpm, dd 40; sand and gravel from 82 to 88 ft underlies till and layers of sand and clay (mixed deposits).
257-608-1	Minnie Nilsson	1945	Drv	r24	r21	1 1/2	--	Sand	520	--	--	L100	9/ 9/59	D	Hard; scr 3.
-2	Syracuse Sand and Gravel Co., Inc.	1954	Drl	r245	r70	8	r70	Limestone	500	47.1	8/14/61	29	8/14/61	A	H_2S; yield (m) 25 gpm; inadequate for washing plant.
257-615-1	Cedarvale Sand and Gravel Co.	1925	Dug	43	--	24	--	S & G	760	40.2	6/29/61	--	--	A	Hard; clay found beneath sand and gravel at 46 ft.
257-620-1	Charles Black	--	Dug	47	--	36	--	Silt	740	37.4	5/31/61	12	5/31/61	D	
257-621-1	Donald Pelchy	1948	Drl	81	r81	6	--	S & G	880	22.3	6/ 1/61	4	6/ 1/61	D	Hard; iron; yield (r) >30 gpm.
-2	William Pelchy	1956	Drl	r240	r175	6	r175	U Shale	880	r20	1956	4	6/ 1/61	D	Hard; yield (r) 3 gpm.
257-627-1	Charles Clark	a1941	Drl	r227	r65	6	r65	do.	1,020	--	--	3	8/ 1/61	D	Yield (r) 4 gpm.
258-530-2	Olney and Floyd Canning Co.	1952	Drl	60	r60	6	r60	S & G	920	r+6	1953	10	10/ 7/60	A	H_2S; hard; temp 48.0, 10/7/60; flowing 250 gpm, 10/7/60.
258-535-1	Village of Munnsville	1958	Drl	r163	r153	8	--	do.	680	r+6	1958	--	--	PS	Anal; hard; scr 10; yield (m) 100 gpm; emergency supply.
-2	do.	1958	Drl	r67	r57	8	--	do.	680	r+8	1958	--	--	PS	Anal; hard; iron; scr 10; yield (m) 35 gpm.
258-541-1	Silas Brown	1960	Drl	r81	r81	4	--	do.	1,300	r14	1960	1	10/10/60	D	Yield (r) 30 gpm; sand and gravel from 78 to 81 ft underlies till and layers of clay (mixed deposits).
258-543-1	Donald Bennett	a1940	Drl	22	r22	6	--	do.	1,300	11.1	10/24/60	5	10/24/60	D	Yield (r) 50 gpm.
258-556-1	Nelson Westcott	1903	Dug	21	--	36	--	Silt	760	15.0	6/21/61	14	6/21/61	D	Yield (e) <3 gpm.
-4	John Clow	a1953	Drl	r35	r35	6	--	S & G	780	r12	1953	14	9/25/61	D	H_2S.
-5	Mott Franklin	1955	Drl	r72	r72	6	--	do.	770	17.6	7/16/62	6	7/16/62	D, S	
-6	Herbert Lang	1955	Drl	r95	r95	6	--	do.	840	r40	1955	4	7/16/62	D	Hard; yield (r) 10 gpm.
258-557-1	Village of Manlius	1894	Dug	2	--	--	--	Sand	850	--	--	5	6/26/62	PS	Anal; yield (e) 50 gpm; well consists of three 4-inch laterals and one 12-inch lateral; locally called Indian Spring.
-2	Adolph Johnson	a1954	Drl	r285	r285	6	--	S & G	940	135.0	7/16/62	2	7/16/62	D, S	Iron.
258-615-1	Glenn Fellows	a1910	Dug	5	--	36	r5	do.	640	--	--	L16	9/11/59	D	Hard; supplies five families.
258-633-1	Wilfred Rice	1957	Drl	r60	--	6	--	Limestone	580	--	--	L3	10/22/59	D	Hard; iron.
259-543-1	Henry Seitz	1947	Drl	64	r64	6	--	S & G	1,320	19.8	10/24/60	3	10/24/60	D, S	Hard; yield (r) 10 gpm.
259-557-1	Philip Quirk	1950	Drl	r77	r21	6	r21	Limestone	720	r5	1959	--	--	D	Yield (r) 25 gpm.
-2	Justin Cooney	1960	Drl	55	r22	6	r22	do.	740	4.6	6/21/61	7	6/21/61	D	Yield 3 gpm.
259-558-1	Thermold Corp.	1951	Dug	8	--	36	--	S & G	560	2.6	9/25/61	7	9/25/61	I	Hard; yield (m) 45 gpm.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
259-559-1	Ward Sperry	a1948	Drl	r95	r95	6	--	S & G	540	r+4	1948	130	10/10/61	D	Hard; iron.
-3	Village of Manlius	1963	Drl	30	19	12	--	do.	540	12.2	6/26/63	--	--	T, D	Anal; At; hard; probable sustained yield 250 gpm; temp 48.5, 6/26/63.
259-604-1	Village of Jamesville	a1930	Dug	5	3	--	3	Limestone	600	1.8	4/27/61	10	4/27/61	PS	Anal; hard; temp 48.0, 4/27/61; yield (m) 200 gpm; well is a 60 by 4-ft excavation in rock.
259-605-1	Southwood-Jamesville County Water Dist.	1956	Drl	28	2	8	2	do.	600	r9	1956	--	--	T, PS	Anal; hard; yield (m) 400 gpm; bottom of hole is top of Middle Shale Unit.
259-609-1	City of Syracuse	1956	Dug	r37	r25	12	--	S & G	420	r18	1957	--	--	T	Anal; At; hard; yield (m) 1,600 gpm.
259-615-1	Charles Pfeiffer	1959	Drl	207	r185	6	r185	U Shale	920	r48	1959	--	--	C	Yield 15 gpm.
259-623-1	John Burns	1959	Drl	r106	r103	6	r103	S & G	940	r40	1959	2	6/29/61	D	Yield 5 gpm; water from sand and gravel at top of rock.
259-627-1	Cowles Chemical Co.	1961	Drl	r178	r40	12	r10	Limestone	710	r96	1961	7	6/ 9/61	I	Hard; yield (m) 700 gpm, dd 35; temp 53.0, 4/1/64.
-2	Waterbury Felt Co.	--	Drl	r275	--	8	a25	Limestone, M Shale	710	57.8	6/12/61	7	6/12/61	I	Hard; yield (m) 65 gpm.
259-633-1	Frederick Cox	1957	Drl	r100	--	6	--	M Shale	560	--	--	L3	10/22/59	D	H_2S; hard; yield (r) 10 gpm.
259-641-1	Willard Harris	--	Dug	29	--	30	--	Till	460	8.8	9/30/60	34	9/30/60	D	
300-530-1	Warner Levenberger	1957	Drl	r169	--	6	--	M Shale	900	--	--	840	10/ 7/60	S, A	Salty.
300-535-1	Frederick Henriksen	1955	Drl	r62	r62	6	--	S & G	590	--	--	10	10/21/60	D	Hard; yield (r) 15 gpm.
300-550-1	David Brown	1959	Drl	r249	--	6	--	M Shale	540	--	--	350	10/24/63	D	Iron; salty.
300-558-1	Theodore Demmerle	1958	Drl	168	5	6	5	Limestone, M Shale	770	92.7	6/22/61	8	6/22/61	D	Hard; yield (r) 30 gpm.
300-559-1	Village of Fayetteville	--	Dug	6	--	72	a4	Limestone	610	--	--	6	6/22/61	PS	Anal; temp 44.5, 6/22/61.
300-600-1	Adolph Falso	1961	Drl	98	48	8	48	M Shale	530	24.0	10/ 9/61			D	
-2	Frank Mapstone	1958	Drl	r80	r80	6	--	S & G	490	r+4	1961	--	--	A	Hard; reported to flow 2 gpm.
-3	Richard Bornhurst	1951	Drl	r55	r55	6	--	do.	520	r+3	1951	22	10/10/61	D	Hard.
-5	Village of Manlius	1964	Dug	27				do.	520	18.5	11/12/64			PS	
300-601-1	Frederick Schnoor	1953	Drl	r95	r95	6	--	do.	590	--	--	24	9/18/61	D	Hard; yield (r) >30 gpm.
300-602-1	Lee Cheney	1957	Drl	r76	r76	6	--	do.	600	r16	1957	14	9/18/61	D	Hard; yield (r) 15 gpm.
-2	Fred Hudson	1950	Drl	47	r47	6	--	do.	590	4.4	9/18/61	10	9/18/61	D	Hard.
300-608-1	H. G. Wright	1948	Drl	r35	r35	6	--	do.	420	r15	1948	--	--	I	Anal; hard; yield (r) 75 gpm.
-2	Valley Dairy		Drl	r31	r31	8	--	do.	420	--	--	--	--	I	Anal.
300-615-1	Arthur Greenway	1952	Dug	17	--	24	17	Till	910	14.6	9/11/59	L8	9/11/59	D	Hard.
-2	Francis Kinney	1956	Drl	179	r60	6	r35	M Shale	960	57.0	9/11/59	L.5	9/11/59	D	H_2S; hard; yield (r) 2 gpm.
300-619-1	Arthur Piekiel	1960	Drl	185	r20	6	r20	Limestone	750	133.0	10/12/60	12	10/12/60	D	Hard; yield (r) 14 gpm.
300-626-1	Henry Haynes	a1954	Drl	r85	r15	6	r15	do.	630	--	--	L8	10/16/59	D, S	Hard; iron; yield (e) >3 gpm.
300-627-1	Cooperdale Dairy, Inc.	1945	Drl	r160	r22	8	r22	M Shale	590	r20	1961	10	8/ 1/61	I	Iron; yield (m) 175 gpm.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
300-627-2	Cooperdale Dairy, Inc.	1949	Drl	r302	--	12	a22	M Shale	590	r20	1961	14	8/ 1/61	I	Iron; yield (m) 240 gpm.
300-628-1	Frederick Peters	1953	Drl	r130	r40	4	r40	Limestone	590	r60	1953	85	6/ 9/61	D	H_2S; hard; yield (r) 10 gpm.
300-642-1	Edward Thurston	--	Dug	17	--	36	--	Till	400	8.7	9/29/59	L420	9/29/59	D	Hard.
-2	Harold Barton	a1954	Drl	116	--	6	--	M Shale	390	2.1	9/29/59	L39,700	9/29/59	A	Hard; iron; salty.
301-530-1	Elgar Simmons	1952	Drl	r53	r53	6	--	S & G	780	r15	1952	280 295	10/10/60 12/18/61	D	Hard; yield (r) 5 gpm.
-2	do.	1951	Drl	r163	--	6	--	M Shale	780	--	--	--	--	De	Salty; water reported much too salty to use.
301-531-1	Howard Rice	1954	Drl	r66	r33	6	r33	Limestone	1,030	r20	1954	13	10/ 4/60	D, S	Hard; yield (r) 6 gpm.
-2	do.	--	Dug	31	--	20	a33	Till	1,030	28.6	10/ 4/60	8	10/ 4/60	U	Inadequate in dry years.
301-538-1	U.S. Air Force	1960	Drl	r200	r10	6	r10	Limestone	1,275	--	--	--	--	In	Anal; hard; yield (r) 12 gpm.
301-551-1	William Bennet	1958	Drl	r46	r45	6	r46	S & G	500	r6	1958	23	10/23/63	D	Hard; yield (r) 55 gpm.
301-558-1	Willis Hills	--	Drl	103	r10	6	r10	Limestone	650	72.5	10/19/61	11	10/19/61	D	Hard.
-2	Ernest Wright	a1948	Drl	184	r16	6	a2	do.	820	131.5	10/19/61	17	10/19/61	D	Hard; yield (r) 3 gpm.
301-559-1	Charles Mitchell	1949	Drl	150	r120	6	r120	M Shale	590	61.2	5/27/60	L94	5/27/60	D	Hard.
301-600-1	McIntyre Bros. Paper Co., Inc.	1958	Drl	r22	r22	6	--	S & G	440	r+20	1961	75	6/22/61	T, A	Hard; temp 49.5, 6/22/61; flowing 125 gpm, 6/22/61.
-2	Village of Fayetteville	1960	Drl	r70	r50	12	--	do.	470	r7	1960	22	9/14/61	PS	Anal; At; hard; scr 20; yield (m) 500 gpm, dd 32 after 1 week.
-3	do.	--	Dug	6	--	168	--	do.	460	--	--	34	9/14/61	PS	Anal; hard; temp 52.5, 9/14/61; flowing 90 gpm, 9/14/61.
-4	John Ogg	1959	Drl	r216	r212	6	--	do.	600	r120	1959	48	9/18/61	D	Hard; iron; yield (r) >30 gpm.
301-601-2	John Jamelske	1939	Drl	r125	--	6	--	M Shale	500	r35	1961	40	10/ 9/61	D	Hard; iron.
301-627-1	Wallen Willis	1937	Drl	r75	r30	6	a10	do.	560	r8	1961	14	6/ 9/61	D	Hard; iron; yield (e) 20 gpm.
-2	G. Edwin Wise	1957	Drl	r52	r30	6	r30	do.	600	--	--	4	6/ 9/61	D	Yield (r) 60 gpm.
301-633-1	Charles Cusick	a1953	Drl	r84	r78	6	r78	do.	610	--	--	L20	10/22/59	D	Hard; iron; yield (r) 20 gpm.
301-638-1	Wilbur Mapley	--	Dug	24	--	24	--	Till	500	19.1	9/29/59	L56	9/29/59	D, S	Hard; inadequate in dry years.
301-640-1	Lester Ohara	1954	Drl	r97	r80	6	r80	M Shale	440	r50	1954	L10	9/29/59	D, S	Hard; iron; yield (r) 15 gpm.
301-644-1	A. P. Dimon and Sons	1952	Drl	r70	r65	8	--	S & G	400	r15	1952	12	9/28/60	C	Iron; scr 5; yield (r) 100 gpm, (m) 40 gpm.
-2	Anthony Recckio	1957	Drl	69	r65	6	r65	M Shale	390	6.2	9/29/60	130	9/28/60	D	Iron; yield (r) 35 gpm; water level affected by pumping of 301-644-1.
-3	do.	1956	Drl	r180	r180	6	--	Clay	380	--	--	--	--	De	Reported dry.
301-646-1	John Wood	1958	Drl	r65	r55	6	r43	M Shale	460	r19	1958	48	9/29/60	D	Hard; yield (r) 25 gpm.
302-532-1	Leroy Burleigh	1951	Drl	r106	r90	6	r90	do.	950	--	--	1	10/ 4/60	D	Hard; iron; yield (r) 7 gpm.
302-536-1	Raymond Temple	--	Dug	41	--	12	--	S & G	530	30.9	10/ 4/60	32	10/ 4/60	D	Hard; iron.
-2	Lavern Harrington	1950	Drl	r262	r262	6	--	do.	550	+6.7	10/ 4/60	295	10/ 4/60	S	H_2S; hard; iron; flowing 5 gpm, 10/4/60.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
302-537-1	Walter Garwood	--	Drl	78	--	6	--	S & G	560	21.3	10/21/60	1,830 1,685	10/21/60 2/15/62	D	H_2S.
302-544-1	David Yorton	1954	Drl	52	r19	6	r19	M Shale	680	30.3	10/19/60	28	10/19/60	D, S	Hard; yield (r) 10 gpm.
302-554-1	Walter Marlowe	1958	Drl	r120	--	6	a5	do.	600	r30	1958	36	4/19/61	D	Hard; iron.
302-555-1	Bryce N. Tuttle	1961	Drl	76	27	6	27	do.	850	57.6	9/14/61			C	Hard; yield (m) 60 gpm.
302-559-1	Lawrence Holden	--	Drl	216	r15	6	r15	do.	690	38.0	5/27/60	--	--	A	
302-600-1	Charles Sherwood	a1948	Drl	r64	--	6	a50	do.	410	r+6	1948	34	5/26/60	S	Hard; iron; temp 51.2, 5/26/60; flowing 6 gpm, 5/26/60.
-3	Ralph Strong	1946	Drl	50	r40	6	r40	do.	470	39.7	11/ 8/61	15	11/ 7/61	D	Hard; yield (r) >30 gpm.
-4	Lester Halsey	a1940	Drv	r18	r16	1 1/4	--	Sand	425	r3	1964	40	7/ 1/64	D	
302-601-1	Charles McGinley	--	Dug	19	--	36	a19	S & G	440	14.2	11/ 3/61	--	--	A	
-2	Edward Wieczorek	a1955	Drl	r40	r40	6	--	do.	430	r10	1955	24	11/ 3/61	D	Hard; yield (r) 20 gpm.
302-602-1	Samuel Chiodo	--	Drl	r30	r30	6	--	do.	410	--	--	28	7/11/61	C	Hard; yield (r) 11 gpm.
302-607-1	Golden Guernsey Dairy	1939	Drl	r170	r130	6	r128	M Shale	430	--	--	--	--	A	Anal; hard; salty.
302-609-1	Hotel Syracuse	--	Dug	36	--	36	--	S & G	395	H		--	--	A, O	At.
-2	Three Sisters Dept. Store	1946	Drl	r65	r55	8	--	do.	395	--	--	1,240	6/27/62	C	At; salty; scr 10; yield (m) 400 gpm.
-3	Brown Jug Restaurant	1946	Drl	56	r46	8	--	do.	400	--	--	1,930	6/27/62	C	Anal; scr 10; yield (r) >100 gpm.
-4	Netherland Dairy, Inc.	--	Drl	r132	--	8	--	do.	400	--	--	--	--	I	Anal; salty; yield (m) 500 gpm.
302-624-1	Glen Hiltbrand	1949	Drl	r47	r47	6	--	do.	470	r12	1960	8	5/ 5/64	S, U	Hard.
-2	Clarissa Scranton	1952	Drl	r35	r35	6	--	do.	480	--	--	10	5/ 5/64	D, S	Anal; hard.
302-627-1	Michael Moore	1957	Drl	50	--	6	a30	M Shale	550	19.8	10/ 6/59	L2	10/ 6/59	D, S	Hard; drilled inside inadequate dug well.
-2	Robert Peer	1959	Drl	r240	r80	6	r29	do.	640	--	--	L3	10/16/59	D	Anal; hard; yield (r) <1 gpm; well was originally 65 ft deep with yield (r) of 10 gpm but filled with soft shale; well deepened and soft zone cased off.
302-629-1	Village of Weedsport	--	Dug	5	--	--	--	Till	590	--	--	--	--	PS	Anal; hard; well consists of collecting basin and 4-inch diameter tile lateral.
302-633-1	Hannah Parkman	--	Dug	25	--	36	r25	do.	490	19.9	10/22/59	L57	10/22/59	D	Hard.
-2	Village of Weedsport	1948	Dug	r13	--	300	--	S & G	420	--	--	16	11/ 2/60	PS	Anal; yield (m) 250 gpm.
-3	do.	1948	Drl	r145	r105	10	r105	M Shale	420	--	--	20	11/ 2/60	PS, U	Anal; yield (r) 200 gpm; emergency supply.
302-635-1	Philip Spinosa	a1953	Drl	39	r20	6	r20	do.	410	18.6	9/29/59	L61	9/29/59	D	Hard; yield (r) 20 gpm.
302-636-1	William O'Hara	--	Dug	16	--	36	--	S & G	430	11.9	9/29/59	L19	9/29/59	U	Hard; inadequate in dry years.
302-645-1	B. G. Dimon	1955	Drl	164	r164	6	--	do.	480	79.5	9/27/60	14	9/27/60	D	Hard; yield (r) 5 gpm.
303-538-1	Milly O'Brien	1942	Drl	r51	r31	6	r30	M Shale	720	r21	1959	32	10/21/60	D, S	Hard; iron; yield (r) 20 gpm.
303-546-1	Herbert Sill	1955	Drl	64	r36	6	r35	do.	530	59.2	10/ 3/60	115	10/ 3/60	D	Hard; yield (r) 20 gpm.
303-549-1	Gilbert Holdridge	1951	Drl	118	--	6	--	do.	570	72.5	10/ 3/60	8	10/ 3/60	D	Hard.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
303-550-1	Ralph Gehring	1954	Drl	r67	r35	6	r35	M Shale	460	r23	1955	110	10/ 3/60	D	Hard; iron; yield (r) 5 gpm.
-2	Edith Thompson	1950	Drl	r37	r37	6	--	S & G	450	r10	1950	13	6/ 9/64	D	Hard; yield (r) 20 gpm.
303-552-1	Village of Chittenango	1953	Drl	r64	r54	18	--	do.	430	r20	1960	16	11/30/60	PS	Anal; hard; scr 10; yield (m) 250 gpm, dd 26; one of two similar wells.
303-554-1	Norman McGowan	1954	Drl	r19	r19	6	--	do.	540	--	--	18	10/ 3/60	D	Hard; iron; yield (r) 30 gpm.
-2	Eldon Nesbitt	1952	Drl	r55	r47	6	r9	M Shale	580	r30	1952	44	10/ 3/60	D	Hard; yield (r) 20 gpm.
303-558-1	William Grygiel	--	Drl	27	27	6	--	S & G	420	14.3	11/ 6/61	8	11/ 6/61	D, Ir	Yield (e) >10 gpm.
303-559-1	Collin Armstrong	1928	Drl	300	r16	6	a10	M Shale	640	117.0	10/19/61	75	10/19/61	D, S	Hard; iron; yield (r) 10 gpm; reported salty when water level is low.
-2	do.	--	Drl	149	--	6	a10	do.	650	128.2	10/19/61	6	10/19/61	D	Iron; inadequate in dry years.
-3	Hamilton Armstrong	1956	Drl	r180	r10	6	r2	do.	560	--	--	38	11/ 7/61	D	Hard; yield (r) 30 gpm.
-4	Edward Teske	1955	Drl	42	r16	6	r16	do.	470	38.9	11/ 7/61	10	11/ 7/61	D	Hard; yield (r) 7 gpm; inadequate in dry years.
303-600-1	Joseph Zappala	1957	Drv	r25	r22	1 1/2	--	S & G	415	r9	1957	L6	5/26/60	D	Hard; scr 3.
-3	Chester Raimondo	a1940	Drl	r25	r25	6	--	do.	430	--	--	L70	5/26/60	D	Hard.
-5	Edward Wilson	1961	Drl	50	50	6	--	Silt	425	22.8	11/ 3/61	36	11/ 3/61	A	Inadequate; yield (r) <1 gpm.
-6	Village of East Syracuse	--	Drl	44	44	18	--	S & G	415	7.8	11/ 3/61	--	--	T, A	Yield (m) 600 gpm from an adjacent screened well, now destroyed.
303-602-1	Davis Wallbridge	1960	Drl	r115	r115	6	--	Silt	410	r3	1960	145	7/11/61	C	Hard; inadequate.
303-609-1	Peoples' Ice Co.	--	Drl	r240	--	8	--	M Shale	400	--	--	--	--	I	Anal; hard; salty.
303-612-1	Allied Chemical and Dye Corp.	1953	Drl	r200	r30	10	r30	do.	400	r35	1953	9,000	1/12/58	I	Hard; yield (m) 245 gpm, dd 18; chloride analysis by owner.
-2	do.	--	Drl	r257	r10	--	r10	do.	400	r56	--	--	--	T, A	Yield (m) 100 gpm, dd 100.
303-613-1	do.	1952	Drl	r300	r30	10	r30	do.	390	r10	1952	--	--	I	Yield (m) 102 gpm.
-2	Village of Solvay	1890	Dug	18	--	180	--	do.	420	--	--	--	--	PS, U	Anal; hard; flowing 200 gpm, 7/5/64.
303-619-2	Samuel Raol	1954	Drl	r38	r38	6	--	S & G	420	+3.4	9/17/59	L76	9/17/59	A	H_2S; flowing 1 gpm, 9/17/59; temp 50.5, 9/17/59.
303-625-1	William Schwarting	1963	Drl	r67	r67	6	--	do.	440	--	--	--	--	D	Hard.
303-628-1	Donald Bard	1949	Drv	r20	r18	2	--	Sand	430	--	--	L28	10/ 6/59	D	Hard; inadequate in summer; scr 2.
303-630-1	Harry Edgbert	1948	Drl	r58	--	6	--	M Shale	410	r36	1949	L8	9/28/59	D	Hard; iron; drilled inside inadequate dug well.
303-631-1	Edward Cartner	a1953	Dug	8	--	24	--	S & G	390	1.7	9/28/59	L9	9/28/59	D	Hard; iron; yield (r) 25 gpm.
303-632-1	Clarence Van Hoover	1956	Drl	r70	r30	6	r30	M Shale	420	r30	1956	L6	9/28/59	D	Hard.
303-634-1	Marvin Kiefer	a1910	Drl	r1,400	--	--	--	--	400	--	--	10,400 11,450	5/23/61 1/ 6/62	A	H_2S; salty; temp 51.5, 5/23/61; flowing 350 gpm, 5/23/61.
303-635-1	Joseph O'Connor	a1941	Drl	r136	r111	6	r111	M Shale	440	r36	1956	12	6/19/61	D, S	Yield (r) 30 gpm.
303-637-1	George Graf	1945	Dug	6	--	36	--	S & G	390	5.4	10/19/59	L49	10/19/59	I	H_2S; yield (r) <10 gpm.
303-638-1	Aaron Wilson	--	Drl	30	30	6	a38	do.	390	7.8	6/19/61	7,350	6/19/61	A	Salty.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
304-530-1	Adam Skachenko	1955	Drl	r115	r13	6	r13	Dolomite	700	--	--	3,750 5,650	10/10/60 2/15/62	D	H_2S; hard; salty; drinking water hauled.
-2	James Fox	1957	Drl	106	13	6	13	do.	700	9.6	10/10/60	335	10/10/60	A	Inadequate.
-3	do.	1958	Drl	75	r13	6	r13	do.	700	12.3	10/14/60	270	10/14/60	D	
304-553-1	Albert Elmer	1945	Drl	39	r39	6	--	S & G	420	10.9	7/ 7/61	7	7/ 7/61	D	Hard.
-2	Monte Mohorter	--	Drv	--	--	1 1/4	--	do.	420	--	--	10	7/ 7/61	D	Do.
304-558-1	William Cooper	1951	Drl	r35	r26	6	r26	M Shale	410	r15	1960	85	11/ 6/61	D	Hard; iron.
-2	Bradley Raynor	a1941	Drl	25	r18	6	--	S & G	410	14.1	11/ 6/61	25	11/ 6/61	D	Hard; iron; bottom of well is uncased in cemented sand and gravel.
304-559-2	Charles Butler	1958	Drv	r60	r57	1 1/4	--	do.	410	--	--	24	11/ 6/61	D	Hard; iron; scr 3; yield (e) 6 gpm; previous driven well had filled with sand.
304-600-1	Melvin Kraft	1951	Drv	r25	r22	1 1/4	--	Sand	405	--	--	L9	5/26/60	C, D	Hard; iron; scr 3; yield (e) >4 gpm.
-2	do.	1957	Drl	r40	--	6	--	M Shale	405	r2	1957	--	--	U	Hard; iron.
304-602-1	George Porpiglia	a1955	Drl	r27	r27	6	--	Sand	410	--	--	120	7/12/61	D	Hard; yield (e) >4 gpm; water contains sand.
304-628-1	Harry Primrose	1958	Drl	100	--	6	a20	M Shale	450	62.2	9/28/59	L7	9/28/59	D, S	Hard; yield (r) 15 gpm.
-2	do.	--	Dug	49	--	24	a20	do.	450	Dry	9/28/59	--	--	A	Inadequate.
-3	Phillip DiRisio	a1950	Drl	r20	r16	6	r16	do.	390	r5	1950	L20	10/ 9/59	D	Hard; yield (r) 55 gpm; some water may be derived from gravel on top of rock.
304-633-1	Howard Jennings	1960	Drl	r84	r65	6	r65	do.	400	r20	1960	17	5/16/61	D	Hard; yield (r) 60 gpm.
304-638-1	Delbert Fyke	1959	Drl	r60	--	6	--	do.	380	r+2	1959	L29	10/19/59	U	Iron; temp 51.5, 10/19/59; flowing <1 gpm, 10/19/59.
-2	Leslie Roarke	--	Dug	27	--	42	--	S & G	390	5.4	10/19/59	L250 300	10/19/59 1/ 6/62	D	Hard; salty.
-3	Dwight Howden	1960	Drl	r94	r94	6	r94	do.	380	--	--	--	--	De	Salty; well drilled through sand except for gravel from 60 to 70 ft.
304-640-1	New York State Dept. of Conservation	--	Dug	18	--	36	--	Till	430	8.2	6/19/61	8	6/19/61	A	Inadequate.
-2	do.	1949	Drl	r153	--	8	--	M Shale	450	--	--	55	6/19/61	D	H_2S; hard; yield (r) 15 gpm.
304-650-1	Robert Sharp	--	Dug	17	--	15	--	Till	400	--	--	--	--	D	Anal.
305-530-1	John Mullaney	1955	Drl	r71	r40	6	r40	Sand-Sh	650	--	--	145 175	10/14/60 2/15/62	D	Yield (r) 1 gpm.
305-541-1	Wayne Leighton	1964	Drl	125	r68	6	r68	Dolomite	425	--	--	--	--	D	H_2S; yield (r) <2 gpm; originally drilled to 75 ft, yield (r) <1 gpm.
305-542-1	William Shanahan	1964	Drl	118	110	6	r109	do.	425	+1.5	4/22/64	60	4/22/64	D	H_2S; yield (r) 30 gpm; flowing 1 gpm, 4/22/64.
305-543-1	Village of Canastota	1964	Drl	113	113	6	--	S & G	405	+18.9	2/17/64	23	4/21/64	T	Anal; flowing 407 gpm, 2/17/64; flowing 377 gpm, 2/19/64 after 43 hours; water level measured in similar well 125 ft away; sand and gravel from 70 to 113 ft underlies clay.
305-545-1	do.	1952	Drl	r70	r50	12	--	do.	410	--	--	102	12/ 1/60	PS	Anal; At; hard; scr 20; yield (m) 600 gpm; known as well number 1.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
305-545-2	Village of Canastota	--	Drl	r70	r50	12	--	S & G	410	+0.1	12/18/61	200	12/18/61	PS	Anal; hard; scr 20; yield (m) 600 gpm, dd 17; known as well number 2.
-3	do.	1941	Drl	65	50	10	--	do.	410	r4	1950	--	--	T	Anal; At; scr 15; yield (m) 480 gpm, dd 5.7; well drilled through clay to 45 ft and gravel from 45 to 65 ft.
305-557-1	Henry Messenger	1946	Drv	r36	r34	1 1/4	--	Sand	405	--	--	40	6/ 2/64	S	Scr 3.
305-558-1	Wilbur Krafft	a1951	Drl	20	r17	6	r17	M Shale	400	8.4	7/12/61	16	7/12/61	D	H_2S; iron; yield (r) 20 gpm.
305-559-1	Floyd Kyser	1918	Dug	16	--	24	--	Sand	400	14.0	11/16/61	10	11/16/61	D	Hard; water contains sand at times.
305-600-2	Paul Costello	1957	Drv	r20	r17	1 1/4	--	do.	400	--	--	L3	5/26/60	D	Hard; scr 3.
-4	Howard Boyce	1949	Drl	r59	r38	6	r38	M Shale	395	r12	1949	175	11/16/61	D	Hard; iron; yield (r) 30 gpm.
305-601-1	Richard Greiner	1959	Drv	20	r20	4	--	Sand	405	7.8	7/12/61	16	7/12/61	D	Water contains sand.
305-605-1	Frank Cavallaro	1949	Drl	r57	r50	6	r25	M Shale	390	r7	1949	--	--	C	Anal; iron; yield (r) 13 gpm; bedrock overlain by alternating layers of clay and very fine sand.
305-607-1	Onondaga Pottery Co.	1941	Drl	r300	r75	6	r75	do.	420	r100	1941	--	--	I	Anal; yield (r) 100 gpm.
305-618-1	Marcel Voumard	1952	Drl	r207	r207	6	--	S & G	400	--	--	50	6/ 2/61	D	Hard; iron.
-2	Albert Donahue	--	Drl	52	r52	6	--	do.	400	+2.0	6/ 2/61	16	6/ 2/61	D	Hard; iron; temp 50.0, 6/2/61; flowing 3.5 gpm, 6/2/61.
305-619-1	James Payne	--	Drl	r180	--	6	a40	M Shale	650	r30	1957	L4	9/17/59	D	Hard; iron.
-2	do.	--	Dug	33	--	24	--	Till	660	18.2 22.3	9/17/59 1/26/61	L24	9/17/59	S	Inadequate in dry years.
-3	Benjamin Isbell	1952	Drl	36	r36	6	--	S & G	440	22.5	6/ 2/61	47	6/ 2/61	D	Hard; iron; yield (r) 15 gpm.
305-621-1	Gerald Snow	1957	Drl	75	r48	6	r48	M Shale	450	19.5	9/25/59	L70	9/25/59	D, S	Hard; yield (r) 3 gpm.
-2	do.	--	Dug	18	--	24	r48	Till	450	11.4	9/25/59	L11	9/25/59	U	Inadequate in dry years.
305-622-1	Olin Cleverly	a1932	Drl	r129	r30	6	r30	M Shale	500	38.0	9/25/59	L12	9/25/59	D, S	Hard.
-2	Charles Webb	1959	Drl	41	r41	6	--	S & G	420	8.9	6/ 2/61	16	6/ 2/61	D	Hard; yield (r) >20 gpm.
305-623-1	Francis Snow	1938	Drl	44	--	6	a15	M Shale	420	23.4	9/25/59	L65	9/25/59	D, S	Hard; iron; drilled inside inadequate dug well.
305-624-1	Kenneth Coon	1940	Dug	7	--	24	--	S & G	420	4.1	9/25/59	L6	9/25/59	D, S	Hard; temp 56.0, 9/29/59.
-2	Arthur Drummond	1956	Drl	58	13	6	13	M Shale	400	14.2	8/ 4/61	395	8/ 4/61	U	Hard.
305-625-1	Glen Clark	--	Drl	82	--	6	--	do.	400	20.5	9/25/59	L4	9/25/59	D	H_2S; hard; iron; drinking water hauled.
-2	Donald Watson	1958	Dug	12	--	48	--	Till	390	10.7	9/28/59	L33	9/28/59	C	Inadequate in summer; yield (e) 1 gpm; 50-ft long trench filled with gravel slopes to bottom of well.
305-626-1	John Clifton	1954	Drl	r78	r15	6	r15	M Shale	470	--	--	L11	9/28/59	D	Hard; yield (r) 20 gpm.
305-629-1	Carol Blanchard	1952	Drl	39	r39	6	--	S & G	430	25.1	10/16/59	L3	10/ 6/59	D	Hard; yield (r) 75 gpm.
305-638-1	Ernest Sherman	--	Dug	7	--	42	--	Till	410	3.8	10/19/59	L5	10/19/59	D, Ir	Hard.
305-645-1	Village of Savannah	1946	Dug	17	12	144	--	S & G	390	5.8	6/25/62	12	6/25/62	PS	Anal; yield (m) 100 gpm.
306-530-1	Leland Shepard	1953	Drl	91	13	6	13	Sand-Sh	660	12.0	10/14/60	370	10/14/60	D	Salty.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
306-544-1	Louis Whitmayer	1959	Drl	r30	--	6	a15	Dolomite	420	--	--	20	8/23/60	D	Hard; yield (r) 4 gpm.
306-548-1	Anthony Sgroi	1929	Drl	r107	r106	6	r106	M Shale	400	r2	1949	320	4/ 6/65	D	Yield (r) 10 gpm; all the water may come from gravel above the bedrock.
306-552-1	Mable Watkins	1943	Drl	r130	r75	6	r75	do.	390	--	--	--	--	De	Salty.
-2	Smith Coulter Co.	1946	Drl	r80	r80	6	--	S & G	385	r5	1946	540	4/22/65	Ir	Hard; iron; salty; yield (r) 35 gpm.
306-555-1	Roy Moth	1944	Drv	r24	r22	1 1/4	--	Sand	405	--	--	6	4/ 6/65	D, S	Scr 2; yield (r) 3 gpm.
306-600-2	Herbert Snyder	1947	Drl	38	r32	6	r32	M Shale	400	2.4	5/26/60	--	--	A	H_2S; hard; iron.
306-629-1	Harvey Picotte	1958	Drl	r87	--	6	--	do.	430	--	--	L3	10/15/59	D	Hard; yield (e) >3 gpm.
306-630-1	Roy Garrett	1956	Drl	52	--	6	a30	do.	420	+.4	10/15/59	L1	10/15/59	D	H_2S; iron; temp 53.5, 10/15/59; flowing <1 gpm, 10/15/59.
306-638-2	Charles Roberts	1944	Drl	203	r69	6	r69	S & G, M Shale	440	37.2	10/20/59	L35	10/19/59	D	H_2S; hard; casing pulled back to expose gravel on top of rock; drinking water hauled.
306-645-1	Bruce Waterman	--	Dug	29	--	36	--	Till	430	21.7	9/27/60	24	9/27/60	D	Hard; inadequate; used for drinking only.
306-649-1	Rayburn Rice	--	Drl	--	--	6	--	M Shale	450	--	--	7	9/23/60	D, S	H_2S; hard; iron; yield (e) >3 gpm.
-2	do.	--	Dug	30	--	36	--	Till	450	25.5	9/23/60	12	9/23/60	U	Inadequate.
-3	Albert Borau	1927	Drl	r127	r65	6	r65	M Shale	440	--	--	10	9/23/60	S	H_2S; yield (r) 5 gpm.
306-651-1	Frank Burt	--	Drl	r105	r91	6	r60	do.	460	65.1	9/27/60	4	9/27/60	D, S	Hard; iron; yield (r) 15 gpm; upper 31 ft of rock cased to prevent caving.
307-543-1	Carlton Shay	1945	Drl	119	8	6	8	Dolomite	420	10.1	8/23/60	1,900	8/23/60	A	Salty; temp 47.5, 8/23/60; chloride sample from bottom of well.
-2	Anna Hilts	1944	Drl	107	34	6	34	do.	415	12.6	8/23/60	2,400 2,550	8/23/60 12/18/61	S	Salty; temp 51.0, 8/23/60; drilled inside inadequate dug well.
307-549-1	Goufore and Tornatore	1936	Drl	80	--	6	a90	Sand	395	--	--	160	4/ 6/65	A	
307-557-1	Howard Klapetzky	a1930	Drl	90	20	6	20	Dolomite	385	6.4	7/12/61	145	7/12/61	A	Iron; yield (r) 25 gpm.
307-559-1	Adolph Den Haese	a1955	Drl	27	r27	6	--	Sand	390	1.7	5/25/60	--	--	Ir	Yield (r) 55 gpm; water contains sand.
307-602-1	Irving Mangel	--	Dug	18	--	24	15	M Shale	410	15.9	10/27/64	26	10/27/64	U	Anal; hard.
307-615-1	Joseph Vinette	1940	Drl	50	r36	6	r35	do.	370	12.8	5/15/61	25	5/15/61	D	
-2	Walter Page	1952	Drv	r57	r54	1 1/4	--	Sand	370	r3	1952	19	5/15/61	D	Scr 3.
-3	Charles Rinaldo	a1940	Dug	7	--	300	--	do.	390	2.0	7/15/64	--	--	C, D	Anal; supplies 9 families and 1 restaurant; flowing 25 gpm, 7/15/64.
307-620-1	Arthur Weigand	a1930	Drl	r55	r39	6	r39	M Shale	460	r12	1959	L66	9/17/59	S	Hard; iron.
307-630-1	John Vogt	1948	Drl	r80	r47	6	r47	do.	410	r19	1957	L215	10/16/59	D, S	Hard; iron; yield (r) 10 gpm.
307-638-1	Town of Conquest	--	Dug	16	--	36	--	S & G	440	12.2	10/20/59	L22	10/20/59	U	Hard.
-2	John Shaffer	--	Drl	52	--	6	--	M Shale	430	27.5	10/20/59	L116	10/20/59	D, S	Hard; iron.
307-641-1	Louis Knapp	1959	Drl	r86	r86	6	--	S & G	410	r16	1959	27	9/28/60	D	Yield (e) >5 gpm.
307-644-1	Kenneth Conrow	1959	Drl	r18	r18	6	--	do.	470	r2	1959	54	9/28/60	S	Yield (r) 15 gpm.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year com-ple-ted	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
307-645-2	Raymond Warrick	--	Dug	17	--	36	--	Till	470	7.2	9/27/60	2	9/27/60	A	
307-647-1	H. S. Noble	--	Drl	r115	r105	6	r105	M Shale	480	--	--	--	--	A	Iron; yield (r) 5 gpm.
307-648-1	Charles Francis	--	Dug	24	--	30	--	Till	490	21.6	9/23/60	18	9/23/60	D	Hard; inadequate in summer.
308-530-1	Harry Milewski	1931	Drl	r83	r30	6	r30	L Shale	560	r8	1954	185	6/20/60	S	H_2S; yield (r) 5 gpm; temp 51.0, 6/20/60.
308-531-1	Orie Folk	1953	Drl	34	r30	6	r30	do.	530	7.4	6/20/60	3	6/20/60	D	Hard; yield (r) 1 gpm; temp 46.0, 6/20/60.
308-533-1	Robert Baker	a1940	Drl	75	--	6	--	Sand-Sh	520	37.0	6/20/60	2,300	6/20/60	D	Salty; temp 51.0 6/20/60; drinking water hauled.
-2	do.	--	Dug	21	--	36	--	Till	520	3.2	6/20/60	20	6/20/60	U	Temp 48.0, 6/20/60; well is contaminated by septic tank 40 ft away.
308-534-1	Verona Water Dist.	1957	Drl	r23	r18	10	--	S & G	470	r2	1961	10	5/ 5/61	PS	Anal; hard; yield (m) 180 gpm.
308-535-1	Lewin Williams	1959	Drl	100	28	6	28	Sand-Sh	470	11.9	7/ 8/60	22	7/ 8/60	A	Yield (r) 2 gpm; inadequate to supply trailer park; temp 46.5, 7/8/60.
308-536-1	Louis Geer	1956	Drl	88	36	6	36	do.	450	3.9	6/21/60	9	6/22/60	D	Anal; H_2S; yield (r) 5 gpm; temp 48.2, 6/21/60.
-2	U.S. Air Force	1951	Drl	r72	r28	6	r28	do.	450	--	--	--	--	De	Anal; salty.
308-538-1	Kenneth Burack	1945	Drl	r81	r60	6	r60	do.	450	r7	1945	5	6/21/60	D, S	Yield (r) 14 gpm.
-2	do.	1945	Drl	172	63	6	63	do.	450	8.5	6/21/60	310	6/21/60	A	Yield (r) <1 gpm; inadequate.
308-540-1	Alvin Hoehn	1954	Drl	r84	r81	6	r80	do.	430	r2	1954	2	6/21/60	C, D	Yield (r) 15 gpm; much of the water may come from sand on top of bedrock.
308-544-1	Clayton Shuler	--	Drl	72	41	6	41	do.	420	16.7	6/29/60	20	6/29/60	D	Yield (e) <4 gpm; drilled inside 27-ft dug well.
-2	Fisher Farms	1951	Drl	124	r40	6	r40	do.	425	--	--	180	6/29/60	D, S	Hard; yield (r) 2 gpm, dd >70.
308-551-1	Joseph O'Brien	1952	Drl	46	36	6	36	do.	380	19.3	6/17/60	10	6/17/60	D	Hard; iron; yield (r) 2 gpm.
-2	do.	--	Dug	14	--	36	a36	Silt and Clay	380	4.5	6/17/60	4	6/17/60	A	Inadequate; temp 46.0, 6/17/60.
308-552-1	Elizabeth Eakin	1960	Drl	85	45	6	45	Sand-Sh	395	15.8	6/17/60	50	6/17/60	D	Yield (r) 5 gpm; temp 47.8, 6/17/60.
308-557-1	Sidney Sachs	1960	Drl	r80	r59	6	r60	Sand	395	7.2	7/12/61	2	7/12/61	D, A	Yield (r) 4 gpm; water contains sand; pumping caused lower 31 ft of well to fill with sand.
308-614-1	Irving Vanderpan	1941	Drl	r93	r93	6	--	S & G	390	r23	1941	60	5/25/61	D	H_2S; hard; iron.
308-615-1	Carl Kunai	1958	Drl	r80	--	6	a20	M Shale	510	r40	1958	50	8/ 1/60	D	Yield (r) 30 gpm.
-2	Robert Post	1957	Drl	48	--	6	a20	do.	510	39.9	8/ 1/60	4	8/ 1/60	D	Hard.
-3	Lawrence Pickard	1960	Drl	114	41	6	41	do.	460	44.1	8/ 1/60	140	8/ 1/60	D	Hard; yield (r) <1 gpm.
308-618-1	Syracuse Ornamental Co., Inc.	--	Drl	r36	r31	16	--	S & G	370	--	--	1,580	6/20/61	I	Yield (m) 1,360 gpm, dd 8.5 after 72 hours; scr 5.
308-620-1	Paul Huntington	1945	Drl	r42	r36	6	r36	M Shale	440	--	--	L6	9/17/59	D	Hard.
-2	Village of Baldwinsville	1889	Dug	r19	--	240	930	S & G	380	--	--	20	6/20/61	PS	Anal; hard; yield (m) 1,150 gpm, dd 2 after 3 hours; known as Canton Street well.
308-630-1	Richard House	1954	Drl	r116	r84	6	r84	M Shale	470	r50	1957	L560 565	10/16/59 12/15/61	D, S	Hard; yield (r) 4 gpm.
308-635-1	Kenneth Wilson	--	Dug	20	--	24	--	Till	450	15.5	10/21/59	L10	10/21/59	D	Hard; inadequate for more than two people.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
308-636-1	Walter Reeves	1952	Drl	90	r30	6	r30	M Shale	470	40.0	10/21/59	L52	10/21/59	D, S	Hard; yield (r) 20 gpm.
308-638-1	Charles Tyler	--	Dug	24	--	24	--	Till	520	17.9	10/21/59	50	12/15/61	U	
308-641-1	Henry Casella	1958	Drl	r105	r100	6	r100	M Shale	400	+3.0	9/27/60	95	9/27/60	D	Hard; iron; flowing 0.5 gpm, 9/27/60.
308-646-1	Douglas Youngman	--	Dug	22	--	30	--	Till	510	19.1	9/23/60	6	9/23/60	A	Inadequate.
309-532-1	Elizabeth Nasto	1956	Drl	r40	--	6	--	S & G	490	--	--	6	6/20/60	D	Hard; yield (r) 5 gpm.
-2	Cleon Morey	1953	Drl	r106	r68	6	r68	L Shale	500	r19	1953	750 975	6/20/60 2/15/62	D	Yield (r) 5 gpm; temp 52.0, 6/20/60.
309-534-1	Albert Anderegg	1954	Drl	r114	r60	6	r60	Sandstone	470	--	--	--	--	A	Water reported too salty to use.
309-536-1	John Ernenwein	--	Dug	28	--	36	--	Sand	445	22.3	10/27/64	50	10/27/64	D, S	Anal; hard.
309-542-1	Harry Simchik	1939	Drl	r129	r61	6	r60	Sand-Sh	400	r18	1958	585	6/21/60	D	H_2S.
309-543-1	George Hammerle	1946	Drl	r81	--	6	--	do.	390	r15	1959	8	6/21/60	C, D	Yield (r) 6 gpm.
309-544-1	Leland Schafer	1959	Drl	94	62	6	62	do.	380	3.2	6/21/60	7	6/21/60	D	Hard; iron; yield (r) 12 gpm.
309-545-1	Anthony Andrello	1960	Drl	r38	--	6	--	do.	375	--	--	11	7/27/64	D	H_2S; yield (e) 20 gpm.
309-547-1	Charles Findlay	1960	Drl	53	46	6	46	do.	410	4.0	6/16/60	3	6/16/60	D	Yield (r) 5 gpm; temp 48.2, 6/16/60.
309-549-1	Donald Thompson	a1950	Drl	44	39	6	39	Dolomite	395	4.9	6/16/60	17	6/16/60	D	Hard; temp 45.5, 6/16/60.
309-551-1	Bridgeport Fire Dept.	1964	Drl	38	14	6	14	Sand-Sh	385	7.8	7/27/64	8	7/27/64	In	
309-555-1	Earl Brownson	1954	Drl	47	43	6	43	do.	405	8.6	6/17/60	15	6/17/60	D	Hard; iron; yield (r) <2 gpm.
309-557-1	Chester Featherly	1940	Dug	8	--	15	--	Silt	385	3.7	6/16/60	15	6/16/60	D	Temp 59.2, 6/16/62.
309-558-1	Chittenango Central School Dist.	1953	Dug	25	--	24	--	do.	385	14.5	5/24/60	L6	5/24/60	In	Inadequate in dry years.
-3	Robert Tubbert	1959	Drl	64	39	6	39	Dolomite	380	4.0	5/24/60	520	4/ 6/65	D	Salty; yield (r) <1 gpm; temp 48.5, 5/24/60.
309-559-1	Oscar Gagnon	1952	Drl	41	--	6	a25	do.	390	11.6	6/15/60	15	6/15/60	D	H_2S; hard; yield (r) 3 gpm.
309-613-1	Vincent Corey	1948	Drv	r33	r30	1 1/2	--	Sand	375	--	--	20	8/ 1/60	D	Hard; scr 3.
-2	Phillip Marion	--	Drl	r147	r147	6	--	S & G	385	--	--	650	4/ 6/65	D	Hard; iron.
309-616-2	Baldwinsville Central School Dist.	1960	Drl	r74	r31	8	r31	M Shale	475	r23	1960	--	--	In	Anal; hard; yield (r) 80 gpm.
309-617-1	Charles Meister	1940	Drl	63	--	6	--	do.	490	32.8	12/ 1/61	41	12/ 1/61	D	Hard.
309-620-1	Village of Baldwinsville	1958	Dug	24	--	96	--	S & G	380	17.1	6/ 6/62	45	6/ 6/62	PS	Anal; hard; yield (m) 500 gpm; known as Tappen Street well.
309-622-1	David McDonnel	--	Dug	28	--	36	--	Till	430	12.1	10/ 2/59	L54	10/ 2/59	D	
309-623-1	Village of Baldwinsville	1961	Drl	r52	r42	8	a55	Sand	380	r7	1961	--	--	T, De	Hard; scr 10; yield 100 gpm; water contained silt.
309-624-1	do.	1961	Drl	91	r81	8	a92	S & G	410	36.5	4/ 5/62	--	--	PS	Anal; yield (m) 528 gpm, dd 1 after 72 hours.
309-625-1	Floyd Snogles	1951	Drl	r56	r56	6	--	do.	430	--	--	L3	10/ 2/59	D, Ir	Yield (r) 13 gpm.
309-626-1	Elbert Dillavough	1958	Dug	12	--	48	--	Till	500	9.2	10/ 2/59	L15	10/ 2/59	C	Inadequate in summer.
-3	Uhl Mann	a1830	Dug	35	--	30	--	do.	500	30.2	10/ 8/59	L143	10/ 8/59	D	Do.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year com-ple-ted	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
309-628-1	DeWitt Pero	1957	Dug	22	--	24	--	S & G	390	19.4	10/ 5/59	L5	10/ 5/59	D	Hard.
-2	Talbert Streeter	--	Dug	23	--	36	--	Till	450	15.8	10/ 8/59	L4	10/ 8/59	D	Hard; inadequate in dry years.
309-629-1	Robert Weston	--	Dug	26	--	36	--	do.	500	20.9	10/ 5/59	L8	10/ 5/59	D	
-2	Kenneth Howell	a1935	Drl	64	--	6	--	M Shale	450	42.4	10/ 8/59	L630	10/ 8/59	D	Hard; iron.
309-630-1	Robert Dudley	a1875	Dug	23	--	36	--	Till	500	19.8	10/ 6/59	L96	10/ 6/59	D	Hard; inadequate in dry years.
-2	do.	1942	Drl	r300	--	6	--	M Shale	510	63.5	10/ 6/59	--	--	A	Salty.
309-631-1	Burton Gallant	a1939	Drl	r75	r55	6	r55	do.	470	r30	1958	L1,280 1,275	10/ 8/59 2/15/62	D, S	Anal; hard; iron; yield (e) <10 gpm; inadequate in dry years.
-3	Clarence Moore	--	Dug	10	--	24	--	Till	480	5.3	10/14/59	L235	10/14/59	A	Hard; iron; inadequate.
309-632-2	Donald Hawker	1955	Drl	r120	r80	6	r80	M Shale	470	r60	1955	L3,560	10/ 8/59	U	Salty.
-3	Harold Sherwood	1948	Dug	8	--	48	--	Silt and Clay	420	1.7	10/14/59	L9	10/14/59	D, S	Temp 50.0, 10/14/59; flowing <1 gpm, 10/14/59; well is dug in area of natural seepage.
309-634-1	Village of Cato	1936	Drl	r52	r42	8	--	Sand	400	r28	1960	40	11/ 3/60	PS	Anal; hard; iron; scr 10; yield (m) 28 gpm.
309-635-1	James Sylvester	1959	Drl	r85	r37	6	r37	M Shale	500	r40	1959	L.5	10/20/59	D	Yield (r) 15 gpm.
309-638-1	Gerald Crowell	--	Dug	25	--	36	--	Till	460	15.5	10/21/59	23	10/15/59	D	Inadequate for more than one family.
309-639-1	Schuler Farms	1944	Drl	r100	--	6	--	M Shale, Dolomite(?)	420	--	--	L522	10/21/59	D	Hard; iron; salty.
-2	Gerald Crowell	--	Dug	20	--	36	--	Till	480	9.3	10/21/59	L12	10/21/59	D	Hard.
-3	Kenneth Crowell	--	Dug	16	--	24	--	do.	430	14.0	10/21/59	75	12/15/61	D	Inadequate in dry years.
309-641-1	Albert Baldwin	1950	Drl	r177	r165	6	r165	M Shale	490	r75	1950	8	9/27/60	D, S	Yield (r) 20 gpm.
309-646-1	Kenneth Kline	--	Dug	12	--	36	--	Till	440	7.1	9/23/60	12	9/23/60	S	
309-651-1	Adrian Van Kouwenburg	--	Drl	r74	r64	6	r64	Dolomite	440	--	--	6	4/ 2/65	D, S	Anal; hard.
310-534-1	Richard Poppleton	1956	Drl	r103	--	6	--	L Shale	470	--	--	340 430	7/ 8/60 9/27/61	D	H_2S; yield (r) 2 gpm.
310-546-1	Mariano Buda	1956	Drl	42	32	6	32	Sand-Sh	370	6.6	6/16/60	35	6/16/60	D	Hard; temp 48.0, 6/16/60.
310-556-1	Cornell University	a1940	Drl	r125	r40	10	r40	do.	390	r75	1940	7	7/28/64	D	Iron; yield (r) 2 gpm.
310-558-1	Conrad Barrett	1940	Drl	r83	r20	6	r20	do.	375	r7	1940	37	5/24/60	D, S	Iron; yield (r) 10 gpm.
-2	do.	--	Dug	21	--	24	r21	Silt and Clay	375	3.1	5/24/60	8	5/24/60	A	Inadequate; temp 46.5, 5/24/60.
310-559-1	Nicholas Merola	1959	Drl	r100	r50	6	r50	Sand-Sh	385	r5	1959	--	--	De	Salty; yield 3 gpm.
310-600-1	Richard Holmes	a1920	Drl	r42	--	6	a5	Dolomite	400	r28	1959	75	6/16/60	D	Hard.
310-601-1	Donald Cornell	1958	Drl	r15	r15	6	r15	do.	385	.4	6/15/60	25	6/15/60	D	H_2S; reported to flow when first drilled; water probably derived from fractured zone on top of rock.
310-602-2	Horace Spurlin	1953	Drl	83	14	6	14	do.	405	6.5	6/13/60	1,300	6/13/60	A	Salty; temp 50.0, 6/13/60; yield (r) <1 gpm.
310-603-1	Henry Hales	a1940	Dug	13	3	24	--	Sand	420	5.2	6/13/60	4	6/13/60	D	Inadequate in dry years; dry 11/4/64.
310-604-1	Rudolph Hall	1958	Drl	r112	r35	6	r36	S & G	415	r5	1958	38	6/13/60	D	Hard; yield (r) 2 gpm; driller reports all water is from gravel on top of rock.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
310-608-1	Pearl Wilcox	a1910	Dug	20	--	24	--	Till	430	5.4	6/ 7/60	40	6/ 7/60	D	Hard; inadequate in dry years; temp 48.3, 6/7/60.
-2	Leslie Weeden	1960	Drl	r60	r35	6	r35	Dolomite	405	r10	1960	50	6/13/60	D	Anal; hard; yield (r) <1 gpm.
310-614-1	Haydukes Motel	1960	Drl	r62	r62	6	--	S & G	375	r8	1960	50	8/ 1/60	C	Hard; yield (r) 45 gpm.
310-615-1	Roy Smith	1954	Drl	74	r70	6	r70	M Shale	420	32.3	6/ 8/60	35	6/ 8/60	D	
310-616-1	Charles Duger	a1953	Drv	r27	r24	2	--	Sand	380	r15	1953	25	6/ 8/60	D	Hard; yield (e) 6 gpm.
-2	John Hourihan	1950	Drl	r120	r50	6	r50	M Shale	380	r20	1950	--	--	De	Inadequate; yield (r) <1 gpm.
-3	Henry Melvin	a1942	Drl	96	r30	6	r30	do.	410	r15	1940	--	--	A	Salty; yield (r) 5 gpm.
310-620-1	Century Radio Corp.	1958	Drl	70	35	6	35	do.	410	5.3	12/ 1/61	L5,380	12/ 1/61	A	H_2S; yield (r) 30 gpm.
310-621-2	Carl Helgeson	--	Dug	31	--	36	--	Till	510	H,22.8	4/26/61	22	4/26/61	O, De	Well destroyed, winter 1963.
310-624-1	Fred and Paul Hafner	1934	Drl	110	--	6	--	S & G	440	59.7	10/ 2/59	L6	10/ 2/59	D, Ir	H_2S; hard.
-2	Howard Mills	1957	Drl	r124	r124	6	--	do.	460	45.4	5/15/61	6	5/15/61	D, Ir	Hard; iron; yield (r) 15 gpm.
310-631-1	John Belzer	1957	Drl	65	r65	6	--	Till	490	14.8	10/15/59	L3	10/15/59	D	Yield (r) <1 gpm; driller reports water is from gravel lens in till.
310-633-1	Herbert Titus	--	Dug	7	--	120	--	do.	410	1.6	10/14/59	L3	10/14/59	D, S	Hard; temp 50.5, 10/14/59; yield (e) 30 gpm; emergency supply for village of Cato.
310-635-1	Jarvis Reynolds	a1900	Dug	18	--	36	--	do.	460	12.8	10/14/59	L2	10/14/59	D	Hard; iron.
-2	Village of Cato	1954	Drl	r54	r8	6	r8	M Shale	440	--	--	44	11/ 3/60	PS	Anal; hard; iron; yield (m) 7 gpm; emergency supply.
310-636-1	Herbert Muhlnickel	1959	Drl	82	r45	6	r45	do.	450	8.1	10/14/59	11	12/15/61	D	Yield (r) 3 gpm.
310-639-1	Walter Hughes	a1922	Dug	13	--	20	--	S & G	420	9.4	10/20/59	L54	10/20/59	D	Inadequate in dry years.
310-643-1	Clifton Burghdorf	1930	Drl	r154	r90	6	r90	Dolomite	500	76.9	4/ 2/65			A	Anal; H_2S; yield (r) 2 gpm.
311-534-1	James Novak	1948	Drl	51	51	6	--	S & G	450	11.2	7/ 8/60	1	7/ 8/60	D, S	Temp 47.0, 7/8/60.
311-610-1	Donald Sotherden	a1910	Drl	22	22	8	--	do.	395	2.9	6/ 7/60	100	6/ 7/60	D, I	Yield (e) >50 gpm; well reported to flow in spring.
311-611-1	Grace Ladd	--	Drl	36	r36	6	--	do.	395	6.7	6/ 7/60	90	6/ 7/60	D	H_2S.
-2	Raymond Tracy	1960	Drl	56	47	6	47	Dolomite, S & G	400	7.5	6/ 7/60	10	4/ 6/65	D	H_2S; temp 48.5, 6/7/60; yield (r) 12 gpm.
311-612-1	Town of Clay	1957	Drl	r45	r40	6	r40	do.	400	r10	1957	5	6/ 7/60	C	Yield (r) 5 gpm; 5 ft of gravel reported above bedrock.
311-614-1	Theodore Kriese	1960	Drl	35	35	6	--	S & G	385	5.6	6/ 8/60	35	6/ 8/60	D	Yield (r) 5 gpm.
311-616-2	George Brown	1960	Drl	41	41	6	r41	do.	370	13.7	7/29/60	2	7/29/60	D	Temp 48.5, 7/29/60; yield (r) 25 gpm.
311-621-1	Douglas Church	1955	Drl	r36	r8	6	r6	Dolomite	430	8.8	9/21/59	L65	9/21/59	D	H_2S; hard; yield (r) 2 gpm.
-2	Robert Church	1945	Drl	47	6	6	6	do.	430	H,9.8	9/21/59	1,260	1/23/62	A, O	At; salty.
311-631-1	Donald Harrington	--	Dug	5	--	24	--	Till	480	2.2	10/16/59	L1	10/16/59	S	Hard.
312-535-1	Roger Gerwig	1960	Drl	93	91	6	r92	Sand	450	7.6	7/ 8/60	5	7/ 8/60	D	Temp 47.0, 7/8/60; yield (r) 6 gpm.
312-543-1	Chauncey Sullivan	1940	Drl	r250	r250	6	--	Clay	375	--	--	--	--	De	Inadequate; very fine sand from land surface to 80 ft cased off; remainder of hole drilled through clay.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
312-543-2	Howard Bencke	1948	Drl	r144	r144	8	--	S & G	375	--	--	--	--	A	Hard; salty; yield (r) 33 gpm; water contained sand.
312-612-1	Earl Loura	1941	Drl	r101	--	6	--	Sand-Sh	395	--	--	22	4/ 6/65	D	Iron; yield (r) 5 gpm.
312-613-1	Scott Sitterly	--	Drl	34	r29	6	r29	Dolomite	385	20.2	5/25/61	40	4/ 6/65	D	H_2S; yield (r) 6 gpm.
312-616-1	Three Rivers Inn	1954	Drl	r132	r50	6	r50	do.	370	--	--	2,700	7/29/60	C, D, A	H_2S; hard.
312-617-1	West Phoenix Co., Inc.	1959	Drl	r52	r40	6	r40	do.	380	--	--	4	7/29/60	C	Yield (r) 20 gpm; supplies restaurant and motel.
312-621-1	Ralph Phelps	1958	Dug	r30	--	24	--	Sand	410	r15	1959	L2	9/21/59	D, S	
312-627-1	Burdette Ferguson	1945	Drl	r100	r17	6	r17	Dolomite	410	r14	1950	16	7/ 6/61	D	
313-536-1	Carolyn Holtz	1959	Dug	23	--	36	--	Sand	430	18.0	7/11/60	2	7/11/60	D	Temp 46.5, 7/11/60; yield (r) 2 gpm.
313-543-1	Harold Holmes	1947	Dug	20	--	24	--	do.	480	12.6	8/26/60	10	8/26/60	D	Temp 52.5, 8/26/60.
313-544-1	North Bay Spring Water System	--	Dug	5	--	36	--	S & G	400	3.0	6/ 7/62	5	6/ 7/62	PS	Anal; reported to flow an average of 70 gpm; 1 of 2 wells supplying village of North Bay.
313-545-1	William Fisher	--	Dug	4	--	36	--	Sand	450	2.0	7/18/60	2	7/18/60	D	
313-546-1	Joseph Reschke	--	Drl	r82	--	6	a60	Sand-Sh	420	50.5	7/18/60	11	7/18/60	C, D	H_2S.
313-547-1	Clinton Peacock	1942	Drl	r167	--	6	--	do.	385	1.2	8/25/60	1,690	8/25/60	A	H_2S.
313-548-1	Marcellus Casket Co.	1927	Drl	r87	r71	6	r70	do.	375	4.0	8/25/60	135	8/25/60	A	H_2S; iron; yield (r) 10 gpm.
-2	Alma Dunning	1960	Drl	100	72	6	72	do.	390	15.5	9/27/61	610	11/13/61	A	Yield (r) <2 gpm.
313-549-1	Leon Caster	1955	Drl	r58	--	6	--	do.	420	3.1	8/22/60	195 100	8/22/60 1/16/62	D	
313-550-1	Joseph Utley	1960	Drl	48	35	6	35	do.	410	+1.0	7/21/60	70	8/25/60	D	H_2S; temp 49.0, 7/21/60; yield (r) 20 gpm; flowing <1 gpm 7/21/60.
313-551-1	Walter Schneeloch	1957	Dug	r20	r20	36	--	Sand	375	r4	1958	1	8/25/60	D	Iron.
313-615-1	Philip Smith	1956	Drl	r52	r40	6	r40	Sand-Sh	370	--	--	17	5/25/61	D	H_2S; iron.
313-617-1	Murray Walker	1960	Drl	25	16	6	16	do.	370	9.0	7/29/60	26	7/29/60	D	Temp 48.0, 7/29/60; yield (r) 20 gpm.
313-621-1	Robert Oram	a1954	Drl	r104	r40	6	r40	do.	410	9.6	9/21/59	L65	9/21/59	D, S	Hard.
314-529-1	U.S. Air Force	1952	Drl	r22	--	--	--	Sand	475	--	--	--	--	De	Anal.
314-537-1	Harold Gillette	1951	Drl	r57	r54	6	--	do.	450	--	--	2	7/11/60	D	Scr 3; yield (r) 4 gpm; originally drilled to 90 ft but filled in with sand; casing pulled to 50 ft and drive point driven to 57 ft.
314-538-1	Ernest Herder	1933	Dug	23	--	36	--	do.	390	18.8	7/11/60	14	7/11/60	D, S	Temp 46.0, 7/11/60; yield (e) 3 gpm.
314-539-1	Mary Haskins	1949	Dug	13	--	36	--	do.	390	9.9	8/26/60	26	8/26/60	D, S	Temp 53.0, 8/26/60.
314-542-1	James Clemins	1959	Drl	r52	r30	6	r30	Sandstone	450	--	--	12	8/26/60	D	H_2S; iron; yield (r) 7 gpm.
314-547-1	Anton Mendl	1954	Drl	r35	r35	6	r35	S & G	520	--	--	2	7/18/60	D	Yield (r) 10 gpm; water from gravel on top of rock.
314-554-2	John Hampson	1955	Drl	101	86	6	86	Sand-Sh	405	17.3	8/25/60	23	8/25/60	D	Hard; iron; temp 50.0, 8/25/60; yield (r) 3 gpm.
314-555-1	Winn's Trailer Park	1955	Drl	r57	r57	6	--	S & G	370	r+6	1955	10	8/24/60	PS	H_2S; yield (r) 40 gpm.
314-556-1	Stephen Aloi	1959	Drl	138	132	6	132	Sand-Sh	390	19.2	8/24/60	665	8/24/60	A	H_2S; salty; yield (r) 8 gpm.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
314-559-2	Frank Lambert	1959	Drl	103	68	6	68	Sand-Sh	395	26.5	8/22/60	34	8/22/60	D	Temp 48.0, 8/22/60; yield (r) 7 gpm.
314-604-1	John Dwyer	a1940	Drl	101	86	6	86	do.	385	19.1	7/25/60	2	7/25/60	D	Hard.
314-614-1	Village of Phoenix	1930	Dug	25	--	300	--	S & G	370	11.9	6/28/62	--	--	PS	Anal; emergency supply.
-2	do.	1948	Drl	r45	r28	24	--	do.	375	r10	1962	6	6/28/62	PS	Anal; scr 15; yield (m) 400 gpm.
314-615-1	Henry Lewis	1961	Drl	r92	r78	6	r77	Sand-Sh	370	r5	1961	--	--	De	Salty; sand and gravel from 52 to 77 ft underlies clay.
-2	do.	1961	Drl	r77	r77	6	r77	S & G	370	r30	1961	4,000 3,550	10/18/61 1/16/62	D	Salty.
-3	John Palmer	1959	Drl	r92	r80	6	r80	Sand-Sh	370	r0	1959	2,870	5/25/61	A	Salty; yield (r) <1 gpm.
314-621-1	Sigmund Brostek	--	Drl	72	63	6	63	do.	380	17.0 12.6	9/22/59 7/ 6/61	500	7/ 6/61	A	Salty.
-2	Leon Burghdurf	1955	Dug	15	--	18	--	Sand	390	10.1	9/22/59	L6	9/22/59	D	
315-538-1	Don Reising	1958	Drl	r98	r98	6	--	S & G	460	r15	1958	4	7/11/60	D	
315-541-1	McConnellsville Water Co.	1962	Drl	r78	r78	6	--	do.	520	r35	1962	11	6/30/64	PS	Anal; yield (m) 18 gpm.
315-546-1	Charles Diable	--	Dug	14	--	36	--	Till	580	11.5	7/18/60	3	7/18/60	D, S	Iron; temp 50.0, 7/18/60.
315-601-1	Central Square School Dist.	a1945	Drl	63	--	6	a90	S & G	440	16.6	8/24/60	50	8/24/60	In	
315-618-1	Robert Haner	1959	Drl	r172	--	6	--	Sand-Sh	400	--	--	345 535	8/ 1/60 9/27/61		Salty.
315-621-1	Great Bear Spring Co.	--	Dug	r10	--	240	--	S & G	390	--	--	6	6/ 6/62	D, Ir	Anal; yield (e) >50 gpm; 1 of 4 similar wells known as Great Bear Springs.
316-530-1	Raymond Kessler	1938	Drl	r220	r220	6	--	do.	540	r40	1954	3	4/22/65	D	Iron; yield (r) 10 gpm; well drilled through very fine sand with gravel at 218 to 220 ft.
316-534-1	Ernest Portner	1934	Drl	r200	r198	6	r199	Sand	460	r5	1934	100	4/22/65	D	Water-bearing sand and gravel at 65 to 73 ft and 130 to 135 ft cased off.
316-538-1	Howard Scott	1930	Drv	r9	r6	1 1/2	--	S & G	400	r7	1959	4	7/11/60	S	Hard; scr 3.
-2	Gerald Scott	1955	Drl	r157	r157	6	--	do.	420	r4	1960	--	--	A	Hard; yield (r) 3 gpm; water contains sand.
316-546-1	Ernest Cain	a1940	Drl	118	90	6	90	Sandstone	620	89.9	7/18/60	2	7/18/60	D	
316-555-1	Lewis Dodge	1959	Drl	102	--	6	--	Sand-Sh	580	28.0	7/20/60	1	7/20/60	D	
316-601-1	Lauri Kukko	1959	Dug	15	--	36	--	Till	490	11.2	8/22/60	2	8/22/60	D	Hard; iron; temp 56.0, 8/22/60.
316-602-1	Kenneth Hayes	1955	Drl	78	55	6	55	Sandstone	460	16.9	8/24/60	38	8/22/60	D, S	H_2S; temp 48.5, 8/24/60; yield (r) 10 gpm.
316-604-1	Jack Sauer	a1945	Drl	22	--	6	a52	S & G	400	7.7	7/25/60	11	7/25/60	D	H_2S.
-2	Ellis Guiles	a1954	Drl	--	52	6	52	Sandstone	400	6.8	8/22/60	475 530	8/24/60 2/15/62	D	Salty; temp 48.0, 8/22/60.
316-617-1	William Phinney	a1950	Drl	116	54	6	54	Sand-Sh	400	19.0	7/28/60	12	7/28/60	D, S	Hard; temp 48.5, 7/28/60.
316-622-1	Richard Howard	1957	Drl	45	r45	6	--	S & G	430	17.3	3/27/61	11	3/27/61	D	Hard; yield (r) 5 gpm.
316-623-1	John Ancona	1959	Drl	169	75	6	75	Sand-Sh	390	r80	1959	--	--	De	Yield (e) <1 gpm; inadequate.
-2	Walter Jasac	--	Drl	r65	r45	6	r45	do.	360	--	--	L2,160	9/22/59	A	Hard; salty.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year com-ple-ted	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
316-623-3	John Ancona	1959	Drl	r130	r90	6	r90	Sand-Sh	390	r60	1959	960 1,850	3/27/61 2/15/62	D	Salty; yield (r) 3 gpm.
317-537-1	Clifford Nelson	1954	Drv	r18	r15	1 1/4	r18	S & G	500	r6	1954	2	7/11/60	D	Scr 3; yield (r) 5 gpm.
-2	Roy MacFarland	1935	Drl	r227	r145	6	r145	L Shale	560	r50	1935	120	8/29/60	D	H_2S; yield (e) <2 gpm.
317-543-1	Ernest Graham	1950	Drl	r161	r161	6	--	S & G	480	r20	1950	12	4/21/65	D	Iron; yield (r) 8 gpm; well drilled through very fine sand with gravel at 160 to 161 ft.
317-546-1	William Evans	1940	Drv	r22	r19	1 1/2	--	Sand	500	--	--	8	7/18/60	D	Scr 3; yield (e) >5 gpm.
-2	Romane Clark	1952	Drl	r105	r105	6	--	S & G	545	r18	1952	3	4/21/65	D	Yield (r) 10 gpm; well drilled through sand to 60 ft, clay from 60 to 104 ft, and sand and gravel from 104 to 105 ft.
317-554-1	John Darling	--	Dug	19	--	24	--	do.	600	14.4	7/20/60	38	7/28/60	D	Temp 49.5, 7/20/60.
317-603-1	James Cunningham	1957	Drl	r92	r92	6	--	do.	450	29.1	7/25/60	2	7/25/60	C, D	Temp 50.0, 7/25/60; bottom 9 ft of well are filled with gravel to filter sand; well drilled through very fine sand with gravel at 92 ft.
317-606-1	Wallace Devendorf	1955	Drl	62	62	6	--	do.	420	10.4	8/19/60	10	8/19/60	D	Temp 48.0, 8/19/60; yield (r) 15 gpm.
-2	Carlton Spooner	1943	Drl	r43	r43	6	--	do.	410	r25	1950	6	8/19/60	D, S	Hard; yield (e) >30 gpm.
317-608-1	Village of Central Square	1929	Dug	r21	--	216	--	do.	390	r11	1960	72	11/29/60	PS	Anal; yield (m) 425 gpm, dd 9.8 after 6 hours.
317-609-1	Chester Chesebro	--	Dug	25	--	24	--	Till	440	21.9	8/19/60	25	8/19/60	D	Temp 49.0, 8/19/60.
317-610-1	Leo Matzke	1955	Drl	87	60	6	60	Sand-Sh	420	r17	1955	155	8/18/60	D	H_2S; hard; yield (r) 2 gpm.
317-617-1	Kenneth Reynolds	1952	Drl	r90	r90	6	r90	S & G	400	22.2	7/28/60	7	7/28/60	D	Yield (r) 20 gpm; driller reports water is from gravel on top of rock.
317-623-1	Carl Truax	1959	Drl	r103	r103	6	--	Sand	430	32.5	9/22/59	L1	9/22/59	D	Yield (r) 10 gpm; bottom 17 ft of well are filled with gravel to filter sand.
-2	City of Fulton	--	Drl	r38	--	30	--	S & G	360	r11	1960	245	3/24/61	PS	Anal; H_2S; yield (m) 400 gpm, dd 17; known as well number 4.
-3	do.	--	Drl	r38	--	30	--	do.	360	r11	1960	48	3/24/61	PS	Anal; yield (m) 340 gpm; known as well number 7.
318-530-1	Clarence Cadrette	1956	Drl	r59	r59	6	--	do.	660	r53	1956	3	8/29/60	D	Yield (r) 6 gpm.
318-531-2	Lee Center Spring Water Co.	1958	Dug	r10	--	102	--	do.	640	--	--	--	--	PS	Anal.
318-533-1	Joseph Rudnik	1958	Drl	r35	r35	6	--	do.	700	r10	1958	8	8/29/60	D	Yield (r) 10 gpm.
318-534-1	Ernest Hardy	1939	Drl	84	r65	6	r65	L Shale	660	23.9	8/31/60	2	9/ 1/60	D, S	Hard; yield (r) 5 gpm.
318-537-1	Harry Ward	a1910	Dug	2	--	150	--	Sand	600	--	--	--	--	PS	Anal; flowing 5 gpm, 6/8/62.
318-538-1	Harold Coons	--	Drl	r130	r130	6	--	S & G	700	59.9	9/ 6/60	1	9/ 6/60	D	Yield (r) 2 gpm; well drilled through sand to 40 ft, clay from 40 to 124 ft, gravel from 124 to 125 ft.
318-541-1	Erwin Kelley	--	Drl	79	79	6	--	do.	560	28.8	8/29/60	1	8/29/60	D, S	Temp 48.0, 8/29/60; yield (r) 10 gpm.
318-546-1	John and Stanley Paff	1947	Drl	r49	r28	6	r27	Sandstone	515	r12	1947	10	4/21/65	D, S	Yield (r) 6 gpm.
318-548-1	U.S. Air Force	1956	Drl	r120	r50	6	r50	do.	510	--	--	--	--	In	Anal; yield (r) 4 gpm.
318-603-1	Cecil York	1959	Drl	42	38	6	38	do.	490	4.6	7/21/60	1	7/21/60	D	Temp 47.5, 7/21/60; yield (r) 20 gpm.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
318-608-1	Robert Johnson	1948	Drl	90	--	6	--	Sandstone	460	41.8	9/ 7/60	2	9/ 7/60	D	
318-615-1	Francis Craner	1947	Drl	r91	--	6	--	do.	440	--	--	8	8/18/60	D	H_2S; iron.
318-617-1	Matt Rauhala	1941	Drl	86	r62	6	r60	do.	450	27.3	7/28/60	3	7/28/60	D	
-2	Robert Kastler	1957	Drl	64	r60	6	r60	do.	450	13.2	7/28/60	1	7/28/60	D	Temp 49.5, 7/28/60.
318-624-1	Nestle Co.	a1920	Drl	r205	r50	10	r50	do.	380	r6	1930	85	3/24/61	I	Yield (m) 125 gpm.
319-537-1	Stanley Nobis	1956	Drl	r74	r74	6	--	S & G	680	--	--	1	7/12/60	D, S	Yield (r) 15 gpm.
319-543-1	Earle Loevenguth	1960	Drl	r86	r86	6	--	do.	500	r30	1960	1	8/29/60	D	Anal; yield (r) 25 gpm.
-2	George Monroe	1960	Drl	100	r100	6	--	do.	500	47.2	9/ 6/60	--	--	D	H_2S; yield (r) 15 gpm.
319-545-1	Clifford Renwick	1950	Drl	r69	r40	6	r40	Sandstone	680	--	--	2	7/15/60	D, S	H_2S.
319-554-2	Veronica Sellinger	1930	Drv	r27	r24	1 1/4	--	S & G	600	--	--	8	7/20/60	D	Scr 3.
-3	Frank Potts	1935	Dug	7	--	12	--	do.	600	2.4	7/20/60	3	7/20/60	D	Iron; temp 54.0, 7/20/60.
319-602-1	Floyd Fisher	1957	Drl	r36	r20	6	r20	Sandstone	490	r16	1957	4	7/25/60	D, S	
319-617-1	James Doss	1956	Drl	r41	r41	6	--	S & G	460	r5	1956	1	7/27/60	D	Yield (r) 15 gpm.
319-618-1	Mildred Du Bois	1957	Drl	r120	r80	6	r80	Sandstone	460	r30	1957	165 155	8/18/60 9/29/61	D	
319-626-1	Merwin Davidson	1959	Drl	r68	--	6	--	do.	390	r20	1959	L531	9/29/59	D	H_2S.
-2	City of Fulton	1958	Drl	r42	--	14	--	S & G	370	--	--	110	3/24/61	PS	Anal; yield (m) 300 gpm; known as North Bay well.
319-627-1	Floyd Kelly	1956	Drl	r70	--	6	--	Sandstone	390	r30	1956	L13	9/24/59	D	H_2S; yield (r) 4 gpm.
-2	Granby Center Methodist Church	1960	Drl	42	42	6	--	S & G	430	8.3	7/26/60	4	7/26/60	In	Temp 48.5, 7/26/60; yield 6 gpm; gravel poured in well to filter sand.
320-537-1	Andrew Kopec	1941	Drl	79	78	6	--	do.	860	12.9	7/12/60	2	7/12/60	D	
320-546-1	Francis Kelly	1945	Drl	r85	r20	6	r20	Sandstone	720	--	--	10	9/ 7/60	D	Anal; yield (r) <3 gpm.
320-547-1	Warner Drought	1958	Drl	r96	r60	6	r60	do.	740	--	--	1	9/ 6/60	D	Iron; yield (r) 30 gpm.
320-603-1	Dominick Caiella	1953	Drl	37	10	6	10	do.	530	13.2	7/25/60	2	7/25/60	D	Iron; temp 50.0, 7/25/60.
-2	John O'Donnell	--	Dug	17	--	20	--	Till	510	15.6	7/25/60	2	7/25/60	D	Temp 50.5, 7/25/60.
320-609-1	Arthur Watson	1959	Drl	r42	r42	6	--	S & G	470	--	--	28	9/ 7/60	D	
320-617-1	Arthur McGinley	a1920	Drl	75	30	6	30	Sandstone	470	31.5	7/27/60	2	7/27/60	D, S	Hard; temp 48.0, 7/27/60.
-2	Ronald McGinley	1959	Drl	43	--	6	--	do.	470	29.6	7/28/60	1	7/28/60	D	
-3	Wallace Whipple	1957	Drl	r68	r68	6	--	S & G	460	--	--	4	7/28/60	D	Yield (r) 15 gpm.
320-619-1	W. W. Hough	1953	Drl	r123	r27	6	r27	Sandstone	440	--	--	85	8/18/60	D	Hard.
320-623-1	Paul Sheldon	1951	Drl	r122	r60	6	r60	do.	430	--	--	5,750 2,100	7/26/60 2/15/62	D	Hard.
-2	do.	1953	Dug	18	--	24	--	Till	430	14.3	7/26/60	90	7/26/60	D	Inadequate in summer; temp 52.0, 7/26/60.
-3	Herbert Cunningham	1960	Drl	r87	r40	6	r40	Sandstone	470	25.7	8/18/60	23	8/18/60	D	Yield (r) 20 gpm.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
321-544-2	Lyndon Armstrong	1955	Drl	32	32	6	--	S & G	640	10.6	7/15/60	15	7/15/60	D	Temp 45.5, 7/15/60; yield (r) 15 gpm.
-3	do.	--	Dug	15	--	24	--	Till	640	10.5	7/15/60	6	7/15/60	U	Temp 48.5, 7/15/60.
-4	John Gage	1964	Drl	r182	r74	6	r74	Sandstone	560	--	--	34	4/21/65	D	Yield (e) <1 gpm; well was originally salty, filled with concrete from 164 to 182 ft and present supply developed.
321-546-1	David Brown	a1958	Dug	16	--	36	--	S & G	525	14.8	7/28/64	4	7/28/64	D	
321-616-1	Mexico Central School Dist.	1955	Dug	29	--	18	--	Sand	450	6.3	7/27/60	1	7/29/60	In	Yield (r) 10 gpm.
-2	James Sanders	1941	Drl	r140	--	6	--	Sandstone	470	--	--	--	--	U	Salty.
-3	Thomas Elhage	1958	Drl	r124	r109	6	r109	do.	480	r35	1958	255 1,145	7/28/60 2/15/62	D	H_2S; yield (r) 5 gpm; drinking water hauled.
321-623-1	City of Fulton	1947	Drl	r75	--	6	--	do.	450	--	--	320	7/26/60	C	Anal; salty.
321-625-1	Ralph McKinney	1957	Drl	83	r74	6	r74	do.	330	18.7	9/23/59	L5	9/23/59	D	H_2S; yield (r) 30 gpm.
-2	Armstrong Cork Co.	1941	Drl	r100	r39	6	r39	do.	370	--	--	--	--	I	Anal; yield (m) 25 gpm.
321-626-1	Birnschul Bowling Corp.	1958	Drl	85	r85	6	--	S & G	350	28.5	9/23/59	L3	9/23/59	C	Yield (r) 12 gpm.
322-537-1	John Collins	a1900	Dug	26	--	30	--	Till	1,060	14.4	7/12/60	14	7/12/60	D	Temp 44.5, 7/12/60.
322-543-1	Village of Camden	1886	Dug	r18	--	72	--	S & G	760	--	--	--	--	PS	Anal; reported to flow 80 gpm; 1 of 3 similar wells known as Lafferty Springs.
322-544-1	Sheldon Metott	1926	Drl	r32	r26	6	r26	Sandstone	800	11.9	7/13/60	8	7/13/60	D	Temp 48.5, 7/13/60; drilled inside inadequate dug well.
-2	Weldon Hague	1950	Drl	32	10	6	10	do.	680	16.5	7/15/60	1	7/15/60	D	Temp 46.0, 7/15/60; yield (r) 12 gpm.
322-547-1	Harold Roberts	--	Drl	r40	r40	6	--	S & G	560	--	--	3	4/21/65	D, S	Yield (r) 8 gpm.
322-553-1	American Telephone and Telegraph Co.	1956	Drl	189	--	6	--	Sandstone	760	28.8	7/19/60	2	7/19/60	C	Yield (e) <8 gpm.
322-556-1	Elmer Brude	1951	Drl	r130	--	6	--	do.	640	50.7	9/ 7/60	88	9/ 7/60	D	Yield (r) 2 gpm.
322-558-1	Michael Roziock	--	Dug	27	--	36	--	Till	640	14.1	9/ 7/60	13	9/ 7/60	D	
322-623-1	Arthur King	1947	Drl	95	--	6	--	Sandstone	460	23.2	7/27/60	4	7/27/60	D	H_2S; yield (r) 3 gpm.
322-626-1	Joel Louis	--	Dug	15	--	48	--	Sand	340	10.9	9/23/59	L4	9/23/59	D	
323-536-1	Joseph Gossner	--	Drl	r66	r66	6	r66	S & G	1,100	--	--	10	7/12/60	D, S	Hard; iron.
323-538-1	Albert Lappin	--	Drl	r33	r33	6	--	do.	1,070	--	--	--	--	D	Yield (r) 6 gpm.
323-544-1	Seth Willson	--	Dug	14	--	63	--	Till	820	6.8	7/13/60	1	7/13/60	D	Temp 49.5, 7/13/60.
323-548-1	Milton Bross	1925	Drv	r40	--	1 1/4	--	Sand	560	--	--	4	7/28/64	D	Water contains sand.
324-524-1	U.S. Air Force	1958	Drl	r280	r24	8	r20	L Shale	1,490	r22	1958	--	--	In	Anal; iron; yield (m) 8 gpm; almost all water is from upper 5 ft of bedrock.
324-532-1	Arnold Genther	--	Drv	r36	r34	1 1/4	--	Sand	1,150	r20	1954	--	--	D	Scr 2; yield (r) 2 gpm.
324-624-1	Sebastian Mistretta	1952	Drl	r117	r30	6	r30	Sandstone	400	--	--	105	7/26/60	D	Inadequate; yield (r) <1 gpm.
324-628-1	James Castiglia	1959	Drl	r208	r70	6	r70	do.	330	r40	1959	--	--	De	Salty.

Table 10.--Records of selected wells in the Eastern Oswego River basin (Continued)

Well number	Owner	Year completed	Type of well	Depth of well (feet)	Depth of casing (feet)	Diameter (inches)	Depth to bedrock (feet)	Water-bearing material	Altitude above sea level (feet)	Water level: Below land surface (feet)	Water level: Date	Chloride concentration: Parts per million	Chloride concentration: Date	Use	Remarks
324-629-1	Anthony Mangano	1950	Drl	57	54	6	54	Sandstone	350	24.3	8/ 2/60	5	8/ 2/60	D	Temp 48.0, 8/2/60; yield (r) 4 gpm.
325-534-1	William Neary	a1885	Dug	12	--	36	--	Till	1,330	3.9	6/22/60	1	6/22/60	D	
325-544-1	Ambrose Ruppert	1955	Drl	r78	r20	6	r20	Sandstone	940	r12	1955	3	7/13/60	D	Yield (e) >30 gpm.
325-545-1	R. B. Taylor	--	Dug	12	--	30	--	S & G	810	r6	1954	6	4/21/65	D, S	Yield (e) 100 gpm.
325-553-1	Sage Estate	--	Dug	9	9	76	--	do.	600	2.6	7/19/60	1	7/19/60	D, In	Temp 45.0, 7/19/60; well supplies school, old-age home and four households.
-2	Dairyman's League	1916	Drl	r80	r75	6	r75	Sandstone	600	--	--	21	7/20/60	In	H_2S; yield (m) 16 gpm.
325-624-1	Robert Burdick	1956	Drl	r65	r40	6	r40	do.	460	--	--	14	7/26/60	D	Yield (r) 10 gpm.
325-630-1	Martin Moshler	1956	Dug	15	--	48	--	Till	380	--	--	--	--	D	Inadequate in summer.
-2	Earle Spaar	1957	Drl	170	r40	6	r40	Sandstone	380	54.6	8/ 2/60	15	8/ 2/60	D	Iron; yield (r) <2 gpm.
326-532-1	Harold Mowers	1946	Drl	r38	r16	6	r15	L Shale	1,400	r16	1949	2	6/28/60	D	Yield (e) <1 gpm.
326-533-1	Clarence Parsons	--	Dug	24	--	36	--	Till	1,440	11.0	6/28/60	3	6/28/60	D	Temp 46.8, 6/28/60.
326-544-1	Paul Clark	--	Dug	16	--	30	16	do.	980	12.6	7/13/60	3	7/13/60	D	Temp 49.0, 7/13/60.
327-536-1	Clifford Freeman	1938	Drl	62	36	6	36	Sandstone	1,320	24.3	6/22/60	1	6/22/60	D	Temp 40.0, 6/22/60; yield (e) >12 gpm.
-2	do.	--	Dug	19	--	48	--	S & G	1,320	15.7	6/22/60	2	6/22/60	A	Inadequate in dry years.
327-543-1	Lawrence Sheehan	1960	Drl	82	20	6	20	Sandstone	1,140	22.0	7/13/60	2	7/13/60	D	Yield (r) 20 gpm.
327-552-1	Harrison Wiggins	1958	Drl	19	19	6	19	S & G	780	9.2	7/19/60	1	7/19/60	D	Yield (r) 10 gpm; water derived from gravel at top of rock.
328-534-1	Lawrence Mathis	a1900	Dug	17	--	36	a30	Till	1,580	9.6	6/27/60	4	6/27/60	D	Hard; temp 48.5, 6/27/60.
328-536-1	Frederick Riegler	1948	Drl	63	63	6	--	S & G	1,360	23.2	6/22/60	1	6/22/60	D	Temp 43.0, 6/22/60; yield (e) >5 gpm; water contains sand at times.
328-543-1	Dewey Ammann	1956	Drl	r67	r58	6	r58	Sandstone	1,280	r7	1956	4	7/13/60	D	Yield (r) 20 gpm; some water may be derived from gravel at top of rock.
328-555-1	Clinton Cox	1963	Drl	r53	r53	6	--	S & G	640	18.9	7/28/64	9	7/28/64	D	Water level in well is that of Kasoag Lake.
329-530-1	David Sims	--	Dug	17	--	32	--	Till	1,600	11.2	6/28/60	14	6/28/60	D	Inadequate in dry years; temp 43.0, 6/28/60.
-2	Herman Schoff	1959	Drl	r150	r100	6	r100	L Shale	1,600	r60	1959	4	6/28/60	D	H_2S; yield (r) 3 gpm.
329-548-1	Theodore Poole	1963	Drl	r76	r54	6	r54	Sandstone	925	r40	1963	13	7/21/64	D	Yield (r) 18 gpm.
329-551-1	Mildred Pappa	--	Dug	18	--	36	--	Till	940	10.4	7/19/60	1	7/19/60	D	Temp 46.5, 7/19/60.
331-531-1	Pearl Weller	--	Dug	11	--	36	11	do.	1,660	4.8	6/28/60	15	6/28/60	S	Temp 46.0, 6/28/60.
333-530-1	Carl Seelman	1956	Drl	r92	r92	6	--	Sand	1,700	r8	1956	4	6/28/60	D	Temp 52.0, 6/28/60; yield (r) 2 gpm; water contains sand at times.
334-531-1	Walter Rudnik	--	Dug	6	--	36	--	Till	1,720	.6	6/27/60	37	6/27/60	S	Temp 52.0, 6/27/60.
335-531-1	Adolph Morczek	1915	Dug	4	--	48	--	do.	1,800	1.3	6/27/60	1	6/27/60	D, S	Hard; temp 44.5, 6/27/60; flowing 2 gpm, 6/27/60.
336-532-1	George McCorduck	--	Dug	17	--	36	--	do.	1,780	10.6	6/27/60	--	--	D	Temp 44.0, 6/27/60.

Table 11.--Records of selected springs in the Eastern Oswego River basin

Spring number: See "Well-Numbering System" in text.

Altitude above sea level: Estimated from topographic maps.

Yield: e - estimated
All others measured.

Chloride concentration: L - analysis made in the U.S. Geological Survey Laboratory. All other values obtained by field analysis.

Use: A - abandoned
D - domestic
PS - public supply
S - stock
U - unused

Remarks: anal - chemical analysis in this report
H_2S - noticeable odor of hydrogen sulfide
hard - water reported to be hard
iron - water contains a relatively high concentration of iron
salty - water tastes salty

Spring number	Owner	Topographic situation	Nature of spring and source of water	Altitude above sea level (feet)	Yield (gallons per minute)	Temperature (°F)	Chloride concentrations (parts per million)	Date of sample	Use	Remarks
249-611-1sp	James Murphy	Hillside, moderate slope.	Stone-lined basin in seepage area; water from relatively permeable till lying on loss permeable till.	1,540	3	53.0	L2	9/16/59	D,S	Anal.
250-624-1sp	George Smith	At foot of hill.	Stone-lined basin in seepage area; water from gravel lying on till.	940	.2	55.0	18	10/17/60	U	Hard.
251-554-2sp	Beecher Burlingham	Hillside, moderate slope.	Stone-lined basin in seepage area; water from gravel lying on clay.	1,220	60	48.0	6	9/22/61	A	Hard.
251-609-1sp	William McFetridge	At foot of hill.	Concrete basin in seepage area; water from till lying on clay.	580	2	49.0	3	10/31/60	D	Hard.
253-609-1sp	George Burghardt	Valley floor.	Unimproved spring in swampy area.	490	e350	54.0	--	11/12/64	U	Anal; H_2S; salty; several smaller springs in area, some of which drain into this spring; springs discharge into Onondaga Creek.
254-554-1sp	Carl Snyder	Hillside, moderate slope.	Concrete basin in seepage area; water from thin till above contact of bedrock formations within the Upper Shale unit.	960	3	47.5	L1	6/15/59	D	Hard; iron.
255-612-1sp	Town of Onondaga	In face of bluff.	Unimproved spring created by removal of sand and gravel in road cut.	540	e30	46.0	13	5/15/64	U	
300-536-1sp	Frank Marshall	Hillside, moderate slope.	Concrete basin in seepage area in gully; water from Middle Shale unit.	700	8	--	5	10/14/60	D,S	Hard.
300-558-1sp	Village of Manlius	Hillside, steep slope; limestone escarpment.	Tile pipes leading from bedding joints in Limestone unit.	620	e50	45.2	6	6/22/61	PS	Anal; one of several springs known as Perry and Costello Springs.
300-642-3sp	New York State	Plain, at southern edge of Montezuma Marsh.	Steel casing, 8 inches in diameter, at site of Indian salt spring.	390	6	51.2	61,000	9/30/60	A	H_2S, iron.
301-619-1sp	Town of Camillus	Hillside, steep slope.	Unimproved spring; water comes from bedding joint in Middle Shale unit.	450	15	49.5	28	10/12/60	U	Hard.
301-626-1sp	Unknown	At foot of hill.	Area around spring is covered with cement; water probably comes from bedding joints in Middle Shale unit.	570	30	--	5	6/12/61	A	
306-623-1sp	Town of Van Buren	Hillside, steep slope.	Unimproved spring created by removal of sand and gravel in road cut.	530	60	48.2	--	10/22/59	U	Known as Whiskey Hollow Spring.
312-627-2sp	Robert Armstrong	Valley floor, on east bank of Ox Creek.	Unimproved spring; water is from bedding joints in Dolomite unit.	390	30	46.0	10	7/ 6/61	D	
315-552-1sp	Village of Cleveland	Valley floor.	Dam built across swampy area; water is from sand and gravel lying on very fine sand and clay.	515	e500	--	--	4/28/61	PS	Anal.
317-545-1sp	William Evans	At foot of hill.	Unimproved spring; water is from sand lying on clay.	460	15	46.2	1	7/18/60	U	
321-537-1sp	Lyman Pierce	Hillside, gentle slope.	Concrete basin; water is from till lying on bedrock.	900	.8	52.5	2	7/12/60	D	
324-553-1sp	Donald Britton	Valley floor.	Natural depression; water is from sand and gravel.	580	15	48.0	1	7/20/60	U	Spring is at headwaters of small tributary to Rowell Brook.